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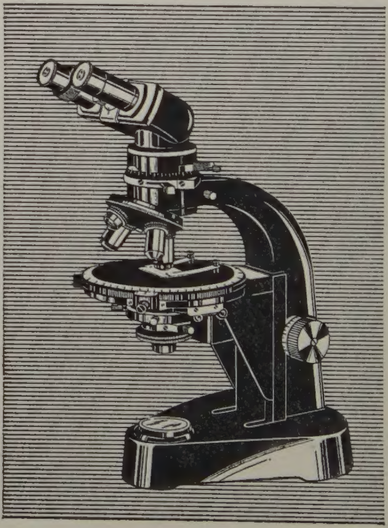

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GEOLOGISKA FÖRENINGENS
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On Some Sedimentary and Tectonic Structures in the Ludlovian Colonus Shale of Scania

By

MAURITS LINDSTRÖM

Abstract. The Lower Ludlovian Colonus Shale of Scania contains instances of probably late Paleozoic folding tending to overthrusting, with axes mainly in NW—SE directions. There may have been several episodes of deformation, of which at least one is probably older than (Borcovician) dolerite dykes. A temporarily exposed section at Skillinge, SE Scania, displays a strong folding as well as sediment structures like groove-casts, flute-casts and load-casts indicating (along with similar structures at other outcrops) sediment transport from W—NW toward E—SE in late Silurian times.

Introduction

In the early autumn 1959, professor Sven Hjelmqvist and professor Gerhard Regnéll discovered that a harbour construction at Skillinge, a village 10 km SW of Simrishamn in SE Scania, was revealing spectacular folds in the Silurian (Lower Ludlovian) Colonus Shales. They suggested to me that the locality would be worth a study, as indeed it proved to be, in several respects. The section is not accessible any more. Since it revealed in a very instructive way features that had so far been little known in Scania, it was appropriate to make a reconnaissance in other parts of Scania of similar features in the sedimentary unit involved. Accordingly, this report deals not only with Skillinge, but also with a number of outcrops, the situations of which are shown by the map, fig. 1.

Dr. J. E. Hede gave me essential information about his earlier observations on sedimentary structures at Skillinge. The investigation would not have been possible without the help of Dr. Ove Persson and Mr. Stig Bergström. Mr. Carl-Axel Larsson, Mr. Sigurd Holmberg, and Mr. R. Lilljeqvist have also given me valuable assistance.

In the following the tectonic structures will be dealt with before the sedimentary ones. This admittedly illogical order is chosen because the tectonic structures are the most obvious and because they may at the present be of the greatest general interest.

Tectonic structures

THE GENERAL PROBLEM

Scania contains the southernmost areas of exposed Archaean crystalline rocks in the Scandinavian peninsula, as well as the northernmost really extensive areas of the Mesozoic sediment cover of Central Europe. These rocks are faulted together with a tract of Cambro-Silurian sediments in the well-developed northernmost clear instances of the Saxonian tectonic style of North-Central Europe, which has earned for the province the reputation of displaying the geologic boundary between the Scandinavian Archaean, conceived of as a unit, and West-Central Europe (see *i.a.* Bubnoff 1952, p. 322). This is certainly a very apt idea, but it might be useful for the time to regard it as purely descriptive.

The faults strike mainly NW—SE and transsect Mesozoic rocks, including Upper Cretaceous (Senonian-Danian rocks are of wide occurrence in SW Scania, but faults have not as far as I know been found in connection with them. However, it can be inferred that they were affected by the faulting earth-movements [cf. Brotzen 1938 and 1940]). Tectonic movements that might be connected with the faulting possibly began in late Paleozoic times (Troedsson 1942) and continued in the passage from Triassic to Liassic (Bölau 1954). The discussion on the faulting has been carried to date in Bölau 1959.

Whereas *i.a.* Voigt (1930) and Troedsson (1932) maintained that folding and/or thrusting played a dominant rôle in creating the NW—SE-striking segments of Scania, Bölau (1959) shows conclusively that the faults transsecting the Mesozoic rocks are normal faults, and that they are thus due to regimes of extension in NE—SW. Weverinck (1936, p. 43) mainly observed normal faults, but mentioned thrusting from the Mesozoic of SE Scania (disproved by Bölau) and from the Archaean and Cambro-Silurian of Löderup, SE Scania.

The present study will show that Paleozoic rocks have largely been deformed by folding and thrusting, and thus that the extension regimes of the Mesozoic were not continuous backward in time.

THE SECTION OF SKILLINGE

The new harbour of Skillinge (1, fig. 1) was dug down in Silurian (Lower Ludlovian) Colonus Shale. The shale, as usual, is light grey and rather soft, not very fissile, and but sparsely fossiliferous. The only fossil identified at Skillinge is the graptolite *Monograptus colonus,* to which the stratigraphic unit owes its name. The shale alternates with beds of sandy siltstone (see below, section on sedimentary structures). The NW wall of the harbour construction offered a continuous, 105 meters long exposure at right angles to the dominant fold axes, thus displaying the plane of deformation. Fig. 2 gives a general diagrammatic view of this section. On the basis of measuring, numerous photographs, and continuous sketches, a drawing on the scale 1: 50 has been prepared of the

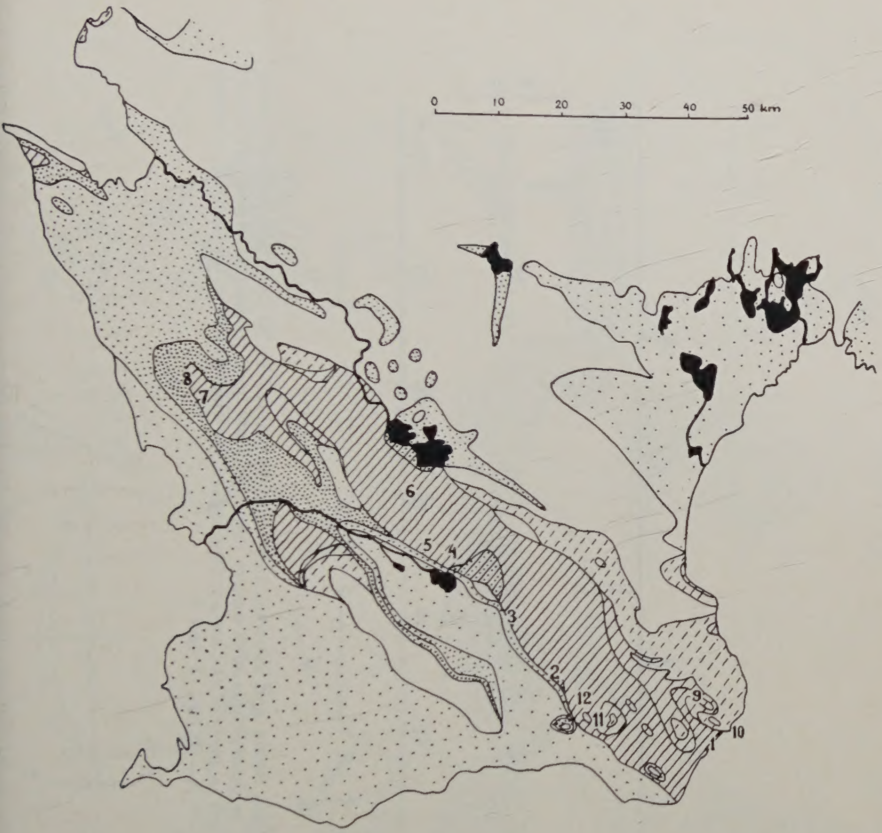


Fig. 1. *Geologic sketch map of Scania, with general locations of outcrops.* Geology after SGU ser. Ba no. 16, map of bedrock of Sweden on the scale 1 : 1,000,000, south sheet, Stockholm 1958. *Signatures:* solid black = lakes and some major watercourses, no signature = Archaean, diagonal lines = Cambro-Silurian (dashes = Cambrian, widely spaced lines = Ordovician, densely spaced lines = Silurian, same with stipples = topmost Silurian), stipples = Mesozoic (dense stipples = Keuper, less dense stipples = Rhaeto-Liassic, widely spaced tipples = Cretaceous). Igneous rocks and Tertiary sediments omitted. *Outcrops*: 1, Skillinge (*i. a.* NW-SE folds). — 2, Ramsåsa (fold, *fide* Moberg & Grönwall). — 3, Tolånga (flute-casts). — 4, Borstbäcken (groove-casts, slight local E-W flexure). — 5, Harlösa (NNW-SSE folds, flute-casts). — 6, Rövarekulan (local ?NW-SE fold). — 7, Sireköpinge (flute-casts). — 8, Rönnarp (dolerite, folds). — 9, Ö. Tommarp (flute-casts, load-casts, NNE-SSW fold). — 10, Gislövshammar (fig. 5). — 11, Tosterup (NNW-SSE folds). — 12, Örup (flute-casts). — *The map does not do justice to the structural complications in SE Scania. I. a.,* the features of the section, fig. 5, can not be identified on the map.

whole section. Figs. 3—4 show selected characteristic details from this drawing. For a precise reconstruction of fold axes, the orientations of available bedding-planes were determined. Where a single fold axis is dominant, the intersections (β) of bedding-planes will tend to coincide with this axis. By graphically constructing the β intersections, one can thus determine the strike of the fold axis.

It appears from the β diagrams for different parts of the section (figs. 3—4) that the main fold axis is horizontal and has the strike N 44° W, or almost

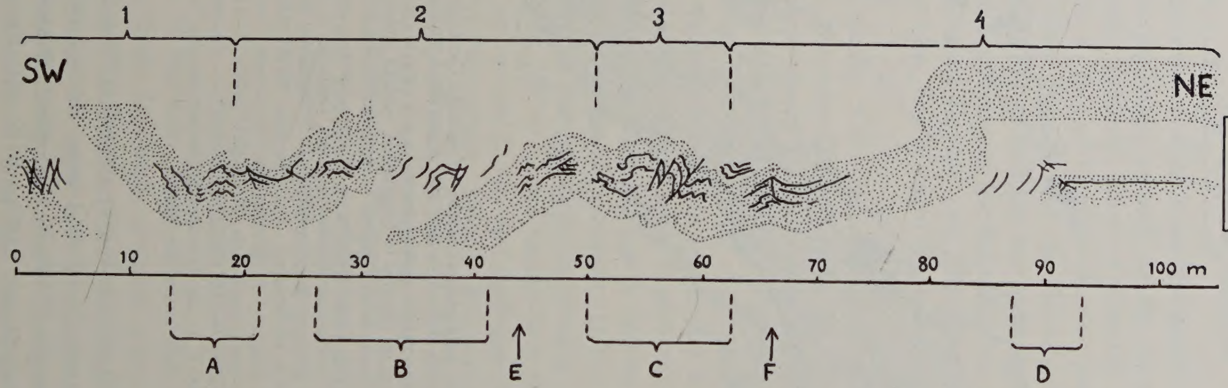
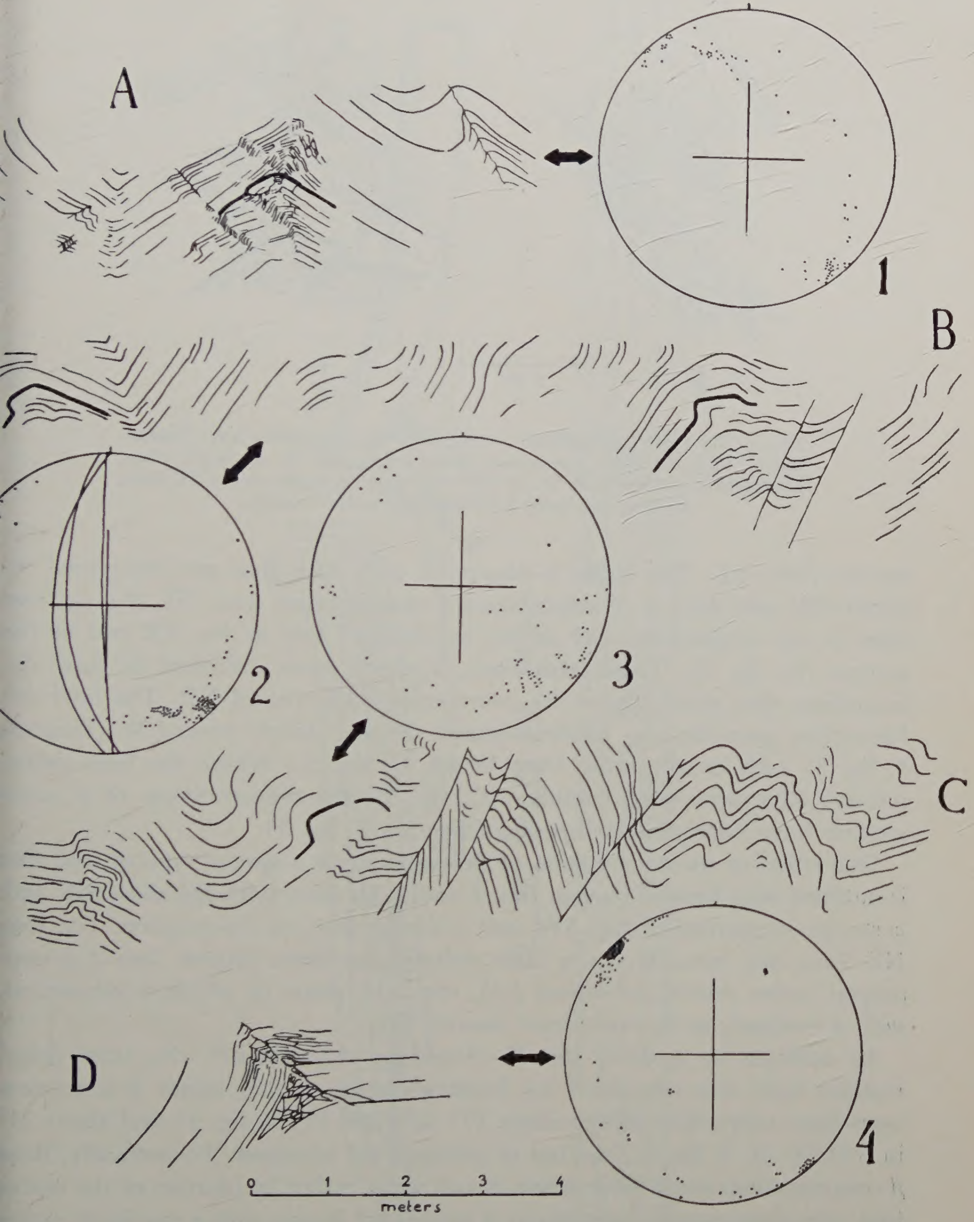


Fig. 2. The section of Skillinge (1, fig. 1). Colonus Shale and siltstone folded mainly about NW-SE axes, with later thrusting from W. To bring out the style of the major folds, arbitrary units of 5 meters thickness have been reconstructed and are shown as alternating bands with and without stipples. 1—4 = parts of the section represented by diagrams 1—4, fig. 3. A—F = details A—F, figs. 3 and 4.



ig. 3. The section of Skillinge, details and fabric (β) diagrams, located in fig. 2. Looking NW. he diagrams are constructed on a Schmidt net, lower hemisphere. — *1.* 78 β intersections from 3 bedding-planes. — *2.* 105 β intersections from 15 bedding-planes; three planes projected are rust-planes. — *3.* 78 β intersections from 13 bedding-planes. — *4.* 136 β intersections from 7 bedding-planes; black spot in NW represents cluster of 62 β intersections. — A-C. Details drawn from field sketches. D, and A in part, are also based on photographs.

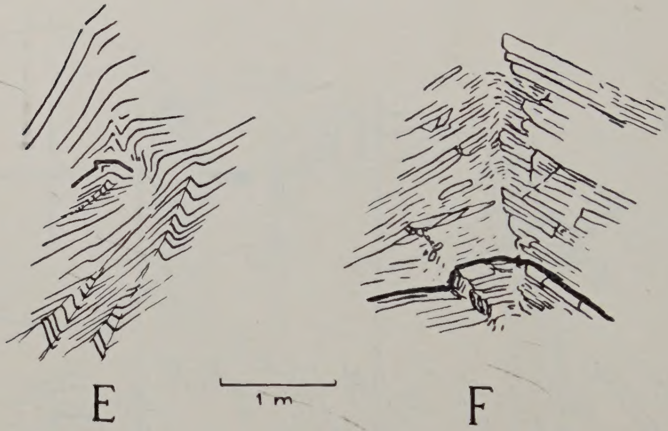


Fig. 4. The section of Skillinge. Details from fig. 2. Looking NW. Characteristic folds, initially overturned toward SW, and in a second phase having been pushed from W (or SW) so as to get a hump on the NE limb, are here and in fig. 3 indicated by a thick contour.

exactly NW—SE. This strike is connected with folds that are overturned towards SW and show a tendency toward overthrusting from NE that is most clear in the magnificent and almost undisturbed fold at the NE end of the section (D, fig. 3). These folds have, however, been disturbed by later deformations that partly threw the overturning back toward NE. The later deformations gave rise *i. a.* to thrust-planes dipping steeply toward W (diagram 2, fig. 3) with overthrusting from W (B, C, fig. 3.) Where the later deformations have been most intensive (C, fig. 3), the concentrations of β intersections have largely been dispersed (diagram 3, fig. 3).

One effect of the combination of deformations is a special type of fold that is outlined with heavier lines in figs. 3 and 4. In these folds the short SW limb is sharpy overturned toward SW, and is due to the first deformation. The long NE limb has, however, by a later deformation been thrown into a hump-shaped rather smooth subsidiary fold, the axial plane of which is subvertical. with a tendency to be overturned toward NE.

In addition to creating the N—S-striking thrust-planes, the later deformations have also reoriented the bedding-planes, so that minor β concentrations have arisen that plunge about 27° in N 24° W (1, fig. 3) and about 21° in S 31° E (2, 3, fig. 3), the last of which is the strongest. Theoretically, these β concentrations could have arisen in two ways: either by rotation of the earlier fold axes along small-circles about a horizontal B-axis with a northerly strike, possibly coinciding with B of the thrusting on the N—S planes, or by a folding about NNW axes of previously not folded portions of the shale (*e.g.*, the long sub-horizontal NE limbs of the first generation of folds). I have previously favoured the first of these interpretations, but after having found other instances of folds striking NNW (at the localities 10 and 5) I am more inclined to ascribe an independent tectonic rôle to these folds, and would now regard

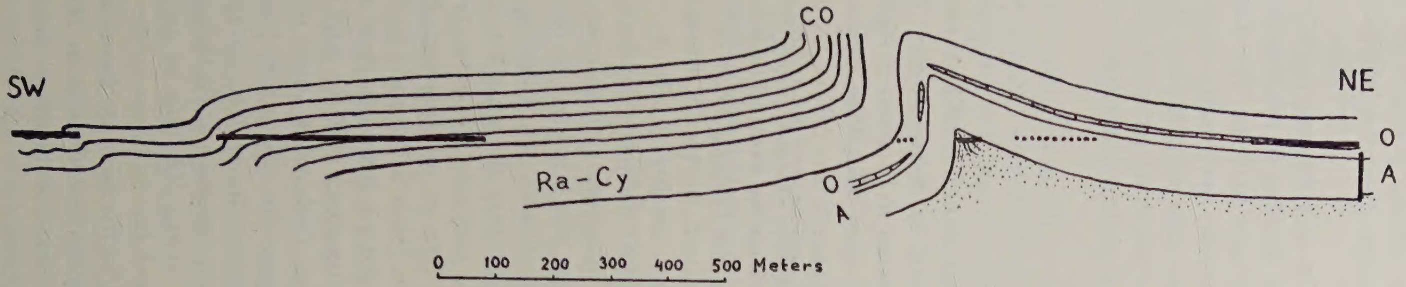


Fig. 5. Hypothetical section along the coast of SE Scania from outcrop 1, Skillinge (SW) to outcrop 10, Gislövshammar (NE). Extent of outcrops in the shore-line is shown by thick lines. Occurrences indicated by numerous pebbles of probably local origin are shown by dots. Boring at Gislövshammar (Westergård 1944) indicated by vertical line. Stippled = Cambrian sandstone. A = alum shale (Cambrian-Tremadocian). O = Ordovician shales (except lower portion of Tremadocian). Limestone band = Ordovician Orthoceras Limestone. Ra—Cy = Rastrites and Cyrtograptus Shales (Llandoverian-Wenlockian). CO = L. Ludlovian Colonus Shale. *Vertical scale = horizontal scale.*

the second alternative as at least equally plausible as the first. The N—S-striking thrusts should then be younger than the NNW-striking folds, for they are not deformed by the latter.

The planes of slip striking N—S and dipping more or less steeply toward W have also been used by normal faulting in addition to thrusting. This was evident along the NE wall of the new harbour. The amount of the faulting varied, the downthrow being, however, never more than 1 meter. The orientations of the slickenside striae on these west-dipping planes indicates down-slip toward SW, for three of the five striae recorded have pitches about 55° toward S 50° W, thus indicating a genetic connection with the Mesozoic normal faulting of Scania.

The tectonic deformation found in the new harbour of Skillinge is younger than the consolidation of the Lower Ludlovian Colonus Shale, for the style of deformation of the shale is somewhat brittle. For a further dating of the folding, one must go to the shore about 300 meters NE of the new harbour, where folded Colonus Shale is transsected by dolerite dykes. The dip of the shale beds varies, but the mean strike seems to be about N 20° W. The folds appear to be cut discordantly by dolerite dykes that strike about N—N 10° E. (There are two dykes, one outcropping about 270 m NE of the new harbour and the other outcropping about 70 m farther NE.) If the dykes are Early Permian (cf. Hjelmqvist 1940, p. 22), the folds are evidently not younger than this age.

About 1 500 meters NE of the new harbour there is S of the small fishing-habitation Gislövshammar an isolated outcrop of Cambrian quartzite that is very strongly shattered by jointing (locality 10, fig. 1). The bedding dips on the average at 64° in N 52° E, with "younging" upward, to judge from well-developed current-bedding. The quartzite contains the fossil burrow(?) *Syringomorpha nilssoni* that indicates that it belongs to the upper portion of the basal Cambrian sandstone of SE Scania (cf. Hadding 1929, p. 103). The orientation of the bedding suggests that the quartzite has reached this level because of thrusting from NE, probably in connection with folding. The quartzite would then be at the core of an anticlinal fold. The presence of outer layers of higher stratigraphic levels is indicated by the abundant presence on the shore of boulders of stinkstone spheroids from the Upper Cambrian alum shales, as well as by the circumstance that the sand on the shore is largely black from alum shale fragments. Ordovician strata outcrop at Gislövshammar 500—600 meters N of the quartzite, where they have been penetrated together with the underlying Cambrian by a Geol. Survey boring (Westergård 1944). The dips of the Ordovician limestone at Gislövshammar are compatible with the idea that they belong to the NE limb of an hypothetical anticline that is overturned toward SW and has its hinge at the quartzite (see fig. 5). The style of this anticline would be the same as that of the big fold at the NE end of the Skillinge section. Its axis would strike in NW—NNW, possibly in N 38° W. The folded Colonus Shale of Skillinge would be situated in the trough following SW of the anticline.

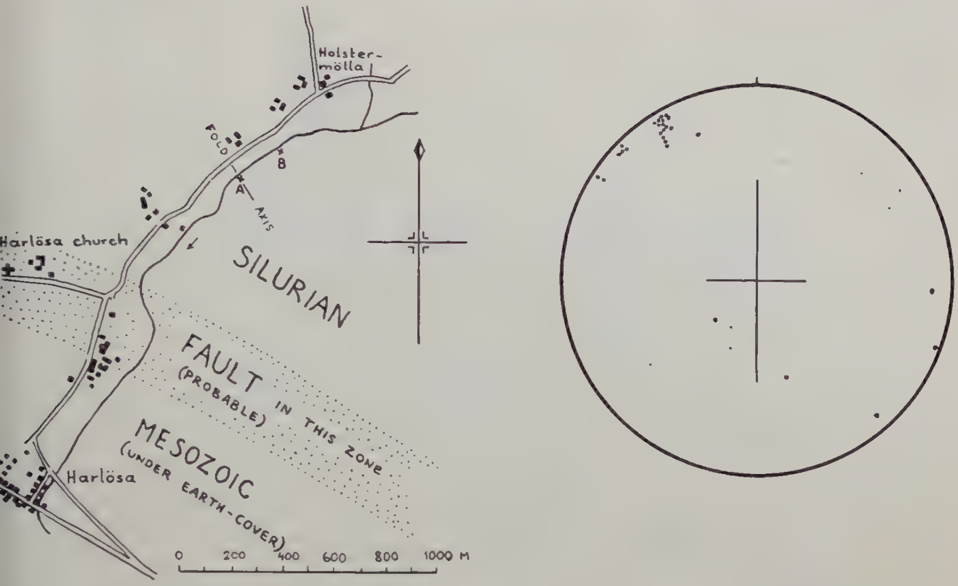


Fig. 6. Sketch map of the Harlösa exposures (5, fig. 1), with fabric (β) diagram for section A. A = section shown in fig. 7, with thrust-folding overriding mainly from NE. B = small exposure of Colonus Shale with flute-casts. In the fabric diagram (Schmidt net, lower hemisphere) small points represent poles of bedding-planes and big points represent their intersections, β. 8 bedding-planes, 28 β intersections.

THE SECTION AT HARLÖSA

About 1 400 meters NE of the village of Harlösa (5, fig. 1) in southern central Scania, the brook flowing from Hjularöd through Harlösa has exposed strongly folded Colonus Shale along its SE bank. The outcrop is very easily accessible from the road between Harlösa and Holstermölla (see sketch map, fig. 6). The shale is light grey and somewhat less arenaceous and more thinly splitting than at Skillinge. There are a few thin bands and lenticles of hard, fine-grained impure limestone.

The orientations of 8 bedding-planes could be determined. This yields 28 β intersections, which would be poor evidence for the discussion of the folding, but for the circumstance that the β intersections are so well concentrated (cf. fig. 6). They indicate a plunge for the main fold axis of 6° in N 34° W. A minor β concentration, possibly insignificant, occurs at N 48° W. The main folds might be correlated with folds striking in N 31—38° W at Skillinge and Gislövshammar (localities 1 and 10, fig. 1).

The deformation plane of the folds (fig. 7) shows a predominant tendency for thrusting from NE, with a main shear plane dipping about 30° in that direction (toward the left in the figure). However, an antithetic shear has developed, the plane of which dips more steeply toward SW, as will be seen in the lower right (SW) part of the figure. Since neither of the shear sets is

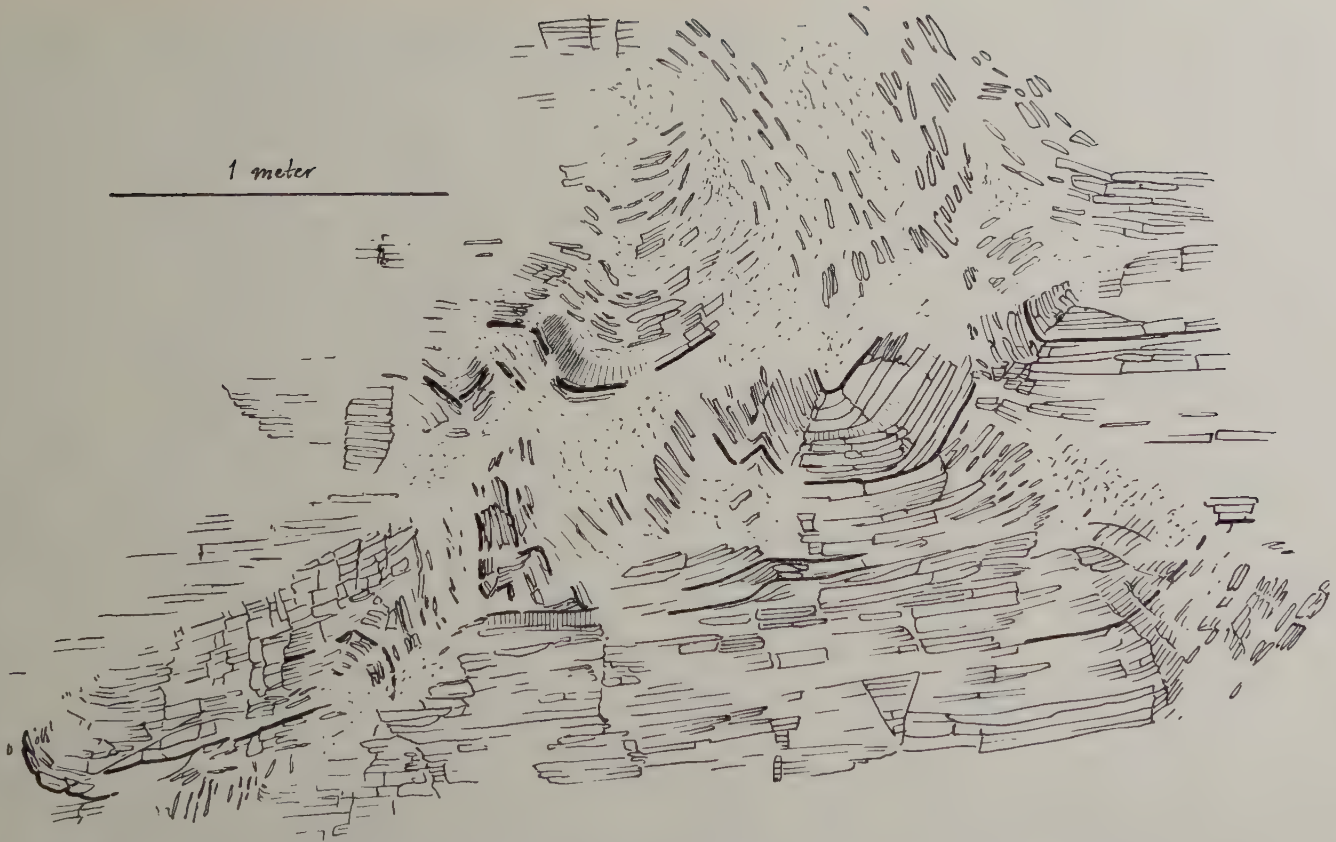


Fig. 7. Folded Colonus Shale at Harlösa (5, fig. 1, A, fig. 6). Looking SE. Stippled areas = strongly brecciated shale. Parallel striations normal to lines of bedding = planes of parting, visible owing to perspective and 3-dimensionality of outcrop. Drawing founded on field sketches and photographs.

evidently deformed by the other, one must conclude that they were active at the same time. The deformation was thus a sub-horizontal NE—SW squeezing, rather than a one-sense thrusting (compare with Skillinge, where the latter NNW—SSE folds largely have sub-vertical axial planes that bear witness of similar conditions of formation).

About 700 meters S of this outcrop passes one of the major NW—SE fault-lines of Scania (Wombseeverwerfung of Voigt 1930, Fyledal line of Weverinck 1936) that, according to Bölau 1959, is a normal fault. SW of the fault are Mesozoic rocks in the valley of the Vomb lake (Liassic-Cretaceous in exposures in areas farther SE), NE of it is Cambro-Silurian. The strike of the fault at Harlösa should be about N 63° W—S 63° E. It cannot have originated at the same time as the folds in the Colonus Shale, with the axis of which it makes a considerable angle (fig. 6). The folds are due to a regime of ENE—WSW compression, whereas the fault, on the contrary, is probably due to extension in NNE—SSW.

THE QUARRIES AT RÖNNARP

NW of the Spargott estate N of Rönnarp (8, fig. 1) there are three quarries for dolerite, which there transsects the Colonus Shale. These quarries have been surveyed by Dr. J. von Feilitzen and Mr. J. Hedelin. I am indebted to them for informing me about their work and for guiding me through the quarries.

The dolerite dykes strike roughly NW—SE. Shale in contact with dolerite has been observed to be folded in at least three places, two of which are in the SE (water-filled) quarry nearest to Spargott. The third place is in the NW (also water-filled) quarry nearest to the main road from Kävlinge to Ängelholm.

In the S wall of the SE quarry, shale has been thrust over dolerite from SW. In connection with the thrusting, a fold has been formed in the shale. The strike of the fold axis is about N 60° W. The amplitude of the fold is just a little over 10 cm. Farther westward along the same wall, in the SW part of the quarry, the shale has been thrown into a fold that plunges 23° in N 20° E and has a wave-length of somewhat less than one meter. The fold is cut discordantly by a wrench-fault striking N 23° W.

The first-mentioned fold, with overthrusting from SW, is clearly younger than the NW—SE dolerite dyke. At Skillinge, dolerite striking N—S appears to be younger than the folds exposed there. The question is, then, if the dolerite dykes belong to one continuous phase of extension with dolerite injection, or not, a question to which there is not any definite answer at present.

The folds in the NW quarry occur in Colonus Shale in the NE wall of that quarry. They are not readily accessible, but appear mainly to strike about N 45° W—S 45° E, although other strikes certainly occur. They vary somewhat in style and wave-length, although they are at least in part overturned toward NE and have wave-lengths less than one meter. They are best developed near the contact between dolerite in SW and shale in NE, and might be due to overthrusting of the dolerite on the shale, in which case these folds would be analogous to the first fold in the SE quarry. However, it is uncertain whether the coincidence of the dolerite-shale contact with the folding is not accidental.

OTHER INSTANCES OF THRUSTING AND FOLDING

Eichstädt (1888, p. 149) seems to have been the first to give a reasonably well-documented hypothetical section of folds in the Silurian of Scania. The folds appear in a N—S section as very smooth undulations with a wave-length of about 3 kilometers. They are postulated for the important Öved area in southern central Scania (E of locality 4, fig. 1). Folds on a smaller scale, as well as small thrusts, are known from several localities and will be dealt with in the following, from SE to NW.

Ö. Tommarp (9, fig. 1). About 700 meters E of the church of Ö. Tommarp there is an outcrop of Wenlockian black Cyrtograptus Shale with cannon-ball-shaped inclusions of impure limestone in the S bank of the small Järrestad river (section 13. XX of Moberg 1910, p. 42 [86]). At the E end of this outcrop, there is a small fold striking N 26° E—S 26° W, with overturning toward ESE. This fold can be regarded as the hinge of an anticline with Cyrtograptus Shale in the core and Colonus Shale (outcropping 50 meters farther E) in the mantle. Sections through Colonus Shale farther east dot not show any evidence of folding.

Löderup (12 km WSW of locality 1, Skillinge). According to Weverinck (1936, p. 43) the Archean gneiss inlier of Löderup is overthrust toward SW on the Colonus Shale along its SW flank. I have not seen this locality.

Tosterup (11, fig. 1). Moberg (1910, p. 116 [160]) gives a sketch of folded (Wenlockian) Cyrtograptus Shale in the ravine of the Munka Tågarpsbäcken in the parish of Tosterup (locality BII: 10 of pl. 5 in Moberg 1910). The folds are overturned from SW, with some thrusting. Although but little is left of the outcrop, it has been possible to expose steeply dipping bedding-planes by digging. The dip determined was 67° toward N 75° E. The structure is thus comparable to the later thrust folds at Skillinge. Furthermore, like the analogous folds at Harlösa (fig. 6) it makes an angle with the adjacent Mesozoic and/or post-Mesozoic fault-line along Fyledalen. The strike of the Fyledal line at Tosterup is NW—SE to WNW—ESE.

Ramsåsa (locality 2, fig. 1). Red sandstone belonging to the topmost Silurian has been quarried about 1 200 meters W of Ramsåsa church (locality F of Moberg 1910, p. 96 [140]). According to Moberg and Grönwall 1909, the N part of the quarry displayed a spectacular fold. At the present the locality is used for a waste-dump, and the rocks are inaccessible, but to judge from Moberg & Grönwall's photographs (1909, pl. 1) and the accompanying text, the fold strikes NW—SE and is overturned toward SW. It may thus be comparable to the first folds of Skillinge.

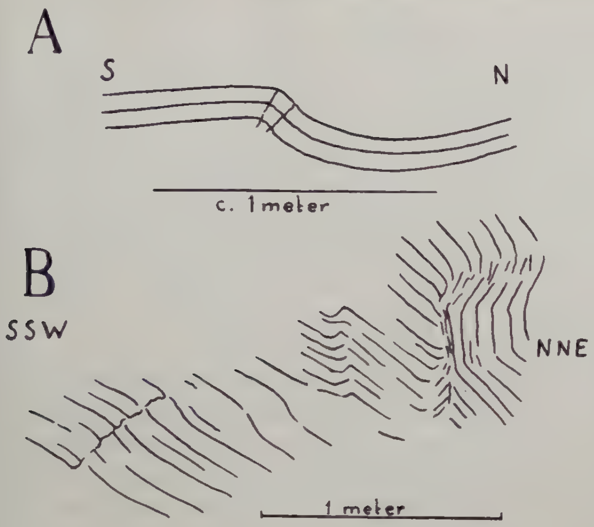


Fig. 8. Crude sketches of folds in Colonus Shale. — A, Borstbäcken (4, fig. 1), about 500 meters SW of Norrigehus, isolated fold striking about N85° W. — B. Rövarekulan (6, fig. 1), east-facing escarpment south of the summer restaurant, isolated (?) folds striking about N57° W.

Borstbäcken (4, fig. 1). Colonus Shale forms somewhat discontinuous outcrops in the steep southern wall of the Borstbäcken valley, about 1 500—400 meters SW of Norrigehus. The shale in the outcrops is generally not perceptibly folded, but about 500 meters SW of Norrigehus there occurs an isolated fold, the general appearance of which is shown by fig. 8A. The strike is about N 85° W—S 85° E, and the overturning is from S. The place of the fold in the regional tectonics is doubtful.

Rövarekulan (6, fig. 1). The extensive outcrops of Colonus Shale at Rövarekulan are as a rule not perceptibly folded. Since the outcrops are aligned along a valley that runs in E—W and SE—NW, *i.e.,* along the mean tectonic strike, it would not in any case be ideal for displaying the style of deformation. In its western parts it runs parallel to the strike of the beds, which are somewhat inclined to the NE. However, in the steep eastfacing outcrops S of the summer restaurant there is a complex fold structure that is sketched in fig. 8B. The strike is N 57° W—S 57° E, and the overturning is toward NE. The structure is thus comparable to the first fold discussed from the quarry at Spargott, Rönnarp, although the similarity of strike and direction of overturning may be incidental. About 550 meters NW of the restaurant, there is in the W bank of the river an outcrop, several meters long, but barely reaching above the water-surface at normal water-level, and largely covered by tree-roots. However, the outcrop appears to display folds with NW—SE axes. This is interesting, for the outcrop lies in the direction of the valley, and it may thus be that the erosion of the river has worked along the hinges of a fold structure. Obviously, the zones of weakness represented by folds would be ideal lines of erosion. Equally obviously, the easily-eroded fold hinges would generally not stand out as outcrops. One may thus infer that folds are underrepresented in the outcrops.

Röstånga (21 kilometers ENE of locality 8, fig. 1). As pointed out by Hadding (1932, p. 392), Moberg (1910, p. 74 [118]) reports on what is probably a small thrust at his locality III: *i* at Röstånga. The rocks involved belong to the uppermost Ordovician. Troedsson (1920, p. 271) regarded the thrust as an instance of subaqueous sliding. He found (p. 275) the line of movement to be S 15° W—N 15° E, the sense of the movement being southward, according to him. This does not agree with the thrust conception according to which the upper block should have moved toward N. I have not seen the structure in question.

CONCLUSIONS ON TECTONICS

Folds and thrusts, often in combination, occur in several of the outcrops of the early Paleozoic of Scania. Because the point of departure of the investigation was an exposure of folded Colonus Shale, and because the Colonus Shale is the most widely occuring rock unit in the Scanian Paleozoic, most of the tectonic structures that have been dealt with are in this Upper Silurian shale. It can be assumed that folds and thrusts are even more important in the Paleozoic of Scania than has become apparent, since deformed strips are probably underrepresented in the outcrops (cf. discussion on Rövarekulan, above).

With respect to orientation, the folds and thrusts can be grouped as follows, *1.* strike N 75—85° W, overriding toward N (Borstbäcken, Röstånga), *2.* strike N 57—60° W, overriding toward NNE (Rönnarp, Rövarekulan), *3.* strike N 38—44° W, overriding toward SW (Skillinge, Gislövshammar), *4.* strike N 15—38° W, no definite sense of overriding (Skillinge, Gislövshammar, Tosterup, Harlösa), *5.* strike N—S, overriding toward E (Skillinge), *6.* strike N(20—) 26° E, overriding toward ESE (Ö. Tommarp, Rönnarp?). It is of course not necessary that structures brought to one and the same group are genetically related, or that structures brought to different groups are not thus related.

Folds striking N 44° W (group 3, above) are at Skillinge older than folds striking N 24—31° W (group 4) and thrusts striking N—S (group 5). The groups 4 and 5 may be related genetically, although I consider it most probable that they are not. N of the new harbour of Skillinge, folds striking about N 20° W (group 4) are evidently older than dolerite dykes striking N—N 10° E. At Rönnarp, dolerite dykes striking NW—SE are older than a fold striking about N 60° W (group 2).

The question of the age of the deformation episodes thus hinges about the age of the dolerites. The youngest rocks transsected by dolerite dykes are topmost Silurian. The younger age limit for the dolerites is set by the Kågeröd beds of probably Keuper age, which contain weathered dolerite pebbles, and which, like the younger fossiliferous rocks, are not intruded by dolerites. With this in mind, one is thus entitled to place the intrusions anywhere in time in the Middle and Late Paleozoic. Hjelmqvist, who has given the problem the most thorough considerations (1940), for lithologic, geographic and tectonic reasons correlates in a general way all the Scanian NW—SE dolerite dykes with the early Permian intrusives of the Oslo area (Borcovician dyke-forming episode of Anderson 1951, p. 43). Whilst one must admit that this hypothesis is most probable, one must keep looking for the definitive proofs for it. One group of dolerites (the melaphyres, cf. Hadding 1916, Hjelmqvist 1940) transsects Silurian rocks of all ages, including the youngest ones, whereas another group (Konga dolerites) does not transsect rocks younger than the Colonus Shale. It has been suggested (by *i.a.* Törnebohm and Hennig 1904, p. 87, and Regnéll 1960) that the Konga dolerites may be late Silurian. This hypothesis, whether probable or not, also lacks conclusive evidence. For consideration in connection with the dolerite problem, one may suggest differences in strike between the two lithologic varieties of dolerite. Incidentally, the melaphyres appear to strike about N—NNW at all the outcrops I have seen, whereas the Konga dolerites typically strike NW—SE.

Since it is probable that Bölau (1959) is right in regarding the Mesozoic and post-Mesozoic tectonics as tensional, I assume that all the folds mentioned in this paper are pre-Mesozoic, even the ones that cannot be dated relative to dolerites, or are younger than the latter. As for the relation between thrusts, folds, and dolerite dykes, there are three logically possible alternatives, considering that some folds are apparently older (Skillinge), and some younger (Rönnarp), than dolerite dykes.

Alternative 1. The dolerite dykes formed during a continuous episode, or series of episodes (Hjelmqvist 1940). Folding occurred earlier (groups 3, 4, pre-Permian?) and later (group 2, late Permian?) in the Paleozoic.

Alternative 2. The folds formed during a continuous series of episodes, without intervening dyke intrusions. Dykes were intruded earlier (late Silurian?, Konga dolerites?, striking NW—SE?, cf. Törnebohm 1904) and later on (early Permian?, melaphyres?, striking N—S to NNW—SSE?).

Alternative 3. Both folds and dykes were formed on different occasions (in a late Paleozoic? — or even mainly early Permian? — episode of oscillation between tension and compression?). — Each of the many question-marks indicates a problem that wants to be solved by special methods.

It may of course be said that the later normal faulting proceeded along planes inherited from the Paleozoic deformation (see particularly Behrens 1953, literature review and discussion, pp. 194—205). Thrust-planes, axial planes of folds, and steep fold limbs would be planes of weakness, along which slip could most easily take place in a considerable range of possible stress-fields. The utilization at Skillinge of N—S striking steep thrust-planes for later slip toward SW illustrates the point. The actual directions of slip could make varying angles with the inherited strikes. However, it is also probable that the Mesozoic and post-Mesozoic extensions created their own slip-planes. Whether this is the case or not with the Fyledal fault-line or any other special instance, must be left to future investigations to prove. However, the Fyledal line does make a considerable angle with folds of probably Paleozoic age at both Tosterup and Harlösa.

Sedimentary structures

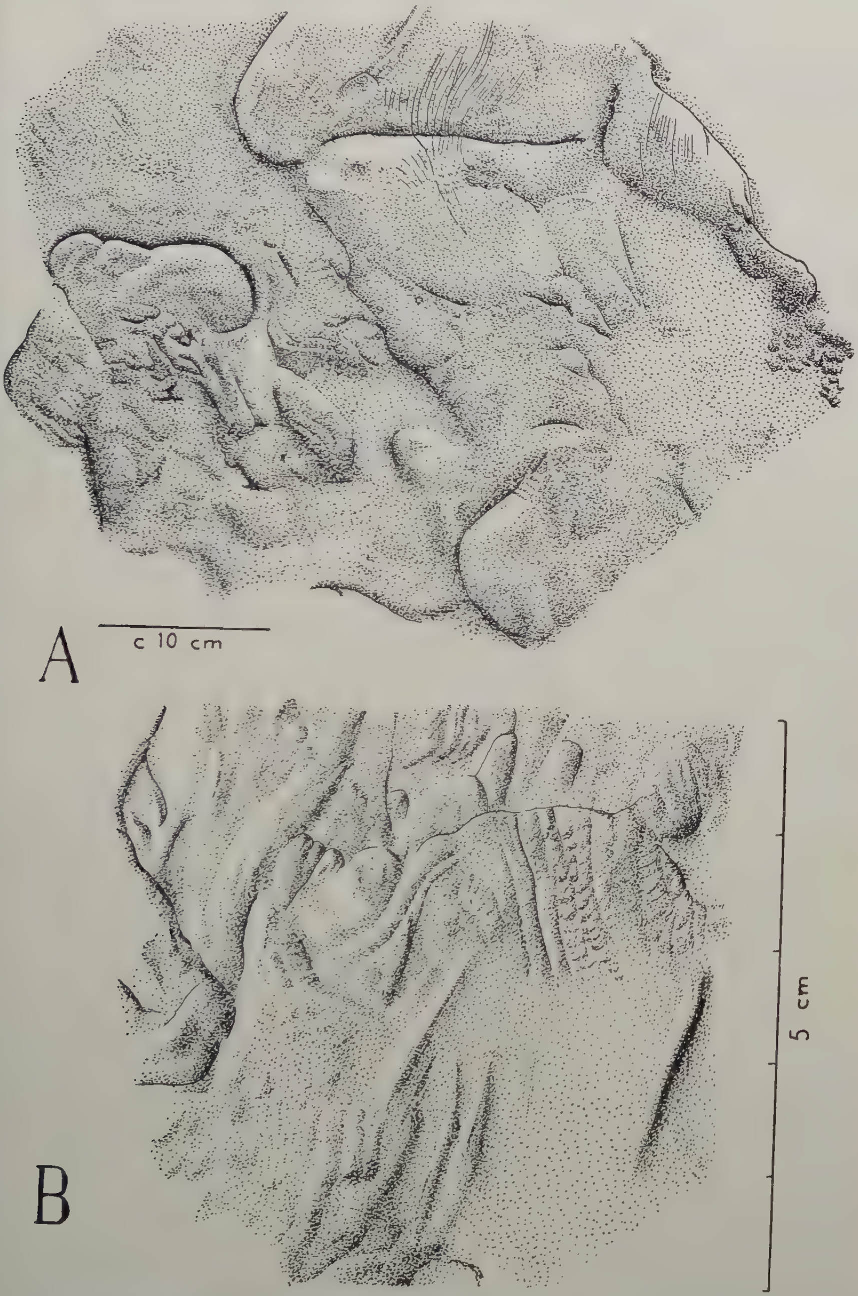
GENERALITIES. THE SECTION AT SKILLINGE

The sediments at Skillinge could be best studied in the NE part of the new harbour. They consist of alternating beds of grey, rather soft mostly unfossiliferous shale and light grey sandy siltstone, rich in white mica of sand size. Details of the lithology will not be discussed here although they certainly are relevant. The siltstone beds contain bands with shale pebbles of a few centimeters diameter. Isolated carbonatic lenticles of a few decimeters diameter and some centimeters thickness occur in the siltstone. The following section was measured at the NE end of the NW wall of the harbour basin.

(Top)	Grey shale with irregular sandy, micaceous pockets and lenticles	0.40 m
	Siltstone, richly micaceous, hardly stratified	0.20 m
	Grey shale	0.20 m
	Barely stratified micaceous siltstone	0.15 m
	Grey shale	0.10 m
	Siltstone, divided into a succession of 6 feebly stratified beds, 10—18 cm thick, separated by 1—2 cm thick shale bands	0.95 m
	Grey shale	0.10 m
	Siltstone	0.06 m
	Grey shale with thin siltstone intercalations	0.24 m
	Grey, sandy micaceous siltstone, divided into an upper 16 cm thick bed and a lower 31 cm thick massive bed	0.47 m
	Grey shale	0.10 m
(Bottom)	Siltstone, divided into a finer upper and a coarser lower half, sharply separated	0.50 m

The soles of the silty beds usually abound in structures like load-casts (Kelling and Walton, 1957, flow-casts of Prentice 1956 and 1960, see fig. 9 of present paper) and groove-casts, which were probably formed in the unconsolidated sediments while deposition was going on.

Prentice (1956, 1960) wants to restrict the term *load-cast* to structures where vertical movement due to unequal loading clearly has played a dominant rôle, and where no sense of horizontal flow can thus be registered. These structures would ideally have random horizontal limits, and must thus be formed only where horizontal flow has ceased entirely. On the other hand, they must be formed in the boundary between two unconsolidated layers with a considerable viscosity, the upper of which has the greatest density. A coincidence of these conditions, the first of which is tranquillity, and the second of which implies rapid deposition, may not be expected to be too frequent, but might occur for instance where material from a turbidity current has come to rest rapidly, for instance in a trough that runs normal to the current direction. A surface (fig. 10B) with load-casts that might have been formed in this way was found on a loose slab at Skillinge. The slab consists of an about 10 cm thick bed of unstratified micaceous siltstone. The structures resemble the interference ripple-load-casts of Kelling and Walton (1957, pl. 17), only, they show



'ig. 9. Sediment structures from Skillinge (1, fig. 1). Overturned load-casts indicating flow during ormation, with minor wrinkles (small "longitudinal ripple-load-casts"). — A. NE wall of arbour construction, looking upward and eastward on sole of bed of sandy siltstone. Note eformed parallel wrinkles in upper (westernmost) portion, center and right. Flow is inferred o have been downward in picture (eastward). After photograph by Mr. Stig Bergström. — B. mall load-casts with flow (downward in figure). Note deformed small "longitudinal rippleoad-casts", and casts of small diapiric structures in upper part of left edge and center of lower dge. In center, diagonal remains of groove-casts. Drawing after specimen. Illumination from the left.

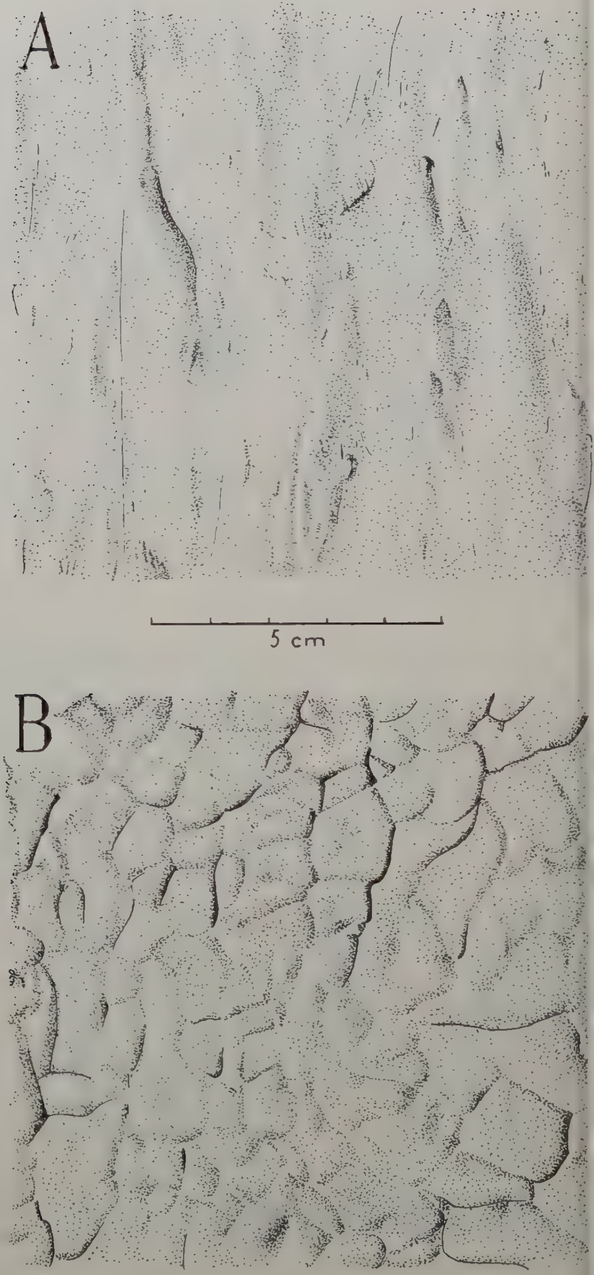


Fig. 10. Sediment structures from Skillinge. — A. Flute-casts groove-casts and bounce-casts in lower surface of bed of silty sandstone. Note small lumps of aggregated sand projecting from surface, often at apices of flute-casts. Drawing after unoriented specimen. — B. Load-casts with semi-random limits, indicating absence of horizontal flow during formation. Drawing after unoriented specimen. — A & B illuminated from the left.

even less preferred orientation than these. They show a superficial resemblance to mud-cracks, with which they have nothing to do, however, for there are not any cracks in the shale underlying the casts, but instead the shale is drawn up as thin, very sharp crests between the polygonal or rounded casts.

Kelling and Walton (1957, p. 487) mention the similarity between the mechanisms of formation of load-casts and diapiric structures like salt domes, both being instances of vertical movements in the boundary between two more or less viscose layers, the upper of which has the greatest density. These authors also point out that a difficulty of interpretation lies in the circumstance that in the case of load-casts, the rising lighter material (fine mud) forms sharp-crested structures, whereas normal diapirs have rounded tops. One may suggest that the solution lies in different kinds of viscosity relations. In salt diapirs, the lighter material flowing upward is less viscose than the upper material that is being penetrated. In load-casts, on the other hand, the settling upper material with the greater density is also probably the least viscose and thus flows more actively than the underlying finer mud that settled earlier and might have been compacted to a certain degree.

Most of the load-casts found at Skillinge are what Prentice (1956, 1960) calls flow-casts, *i.e.*, they show some preferred orientation with overturning mainly in one direction, the direction of flow (fig. 9). They were formed in the lower surface of transported unconsolidated silt, before the motion had ceased entirely. For the instances at Skillinge it can be showed that the amount of the flow during the formation of these load-casts was not very great, for the load-casts deform, but do not destroy, traces of the last stages of suspension-movement. The traces in question consist of long parallel casts, rounded in cross-section and separated by faint grooves, with a wave-length of about 3 mm and an amplitude of about 1 mm (fig. 9A shows the appearance of a surface with deformed wrinkles of this kind. Fig. 9B gives a closer view of structures of this sort). The orientation of these casts is shown by fig. 11. They strike a little north of east, and are roughly normal to the load-casts or flow-casts that deform them. Thus, one may assume that they are parellel to the movement of the silt-suspension. They are very similar to the longitudinal (current-parallel) ripple-load-casts of Kelling and Walton (1957, see particularly pl. 17, fig. 2), although the latter structures have a wave-length that is 3—10 times as great as the one of the Skillinge structures. I refer to the Skillinge structures as small "longitudinal ripple-load-casts". They occur also on surfaces that are not deformed by load-casts.

Groove-casts (Crowell 1955, p. 1358) occur on several surfaces at Skillinge, particularly along the SW wall of the new harbour construction. They occur as fine, dense, rather smooth striations over the whole bedding-planes. They may also, as in the loose slab, fig. 10A, occur singly and be either long or quite short ("bounce-casts"). They may also be one or a couple of centimeters wide, in which case they are often provided with parallel finer striations. They indicate the direction, but not the sense, of the current. The strikes of groove-casts found in the Colonus Shale at Skillinge and other localities are

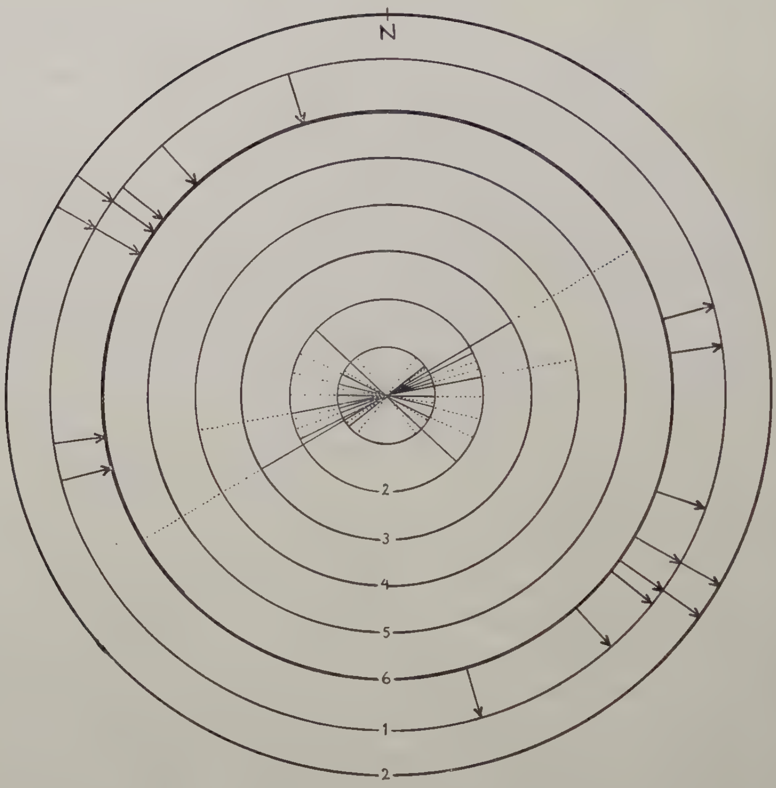


Fig. 11. Orientations of linear sediment structures in the Colonus Shale, outcrops 1, 3, 4, 5, 7, 9, 12. Two outer circles: flute-casts, with arrows indicating sense of flow during formation. Inner circles: groove-casts (full lines) and small "longitudinal ripple-load-casts" (stipples) added together.

shown in fig. 11 (full lines). At Skillinge, they strike about W—E the current direction, as indicated by the load-casts, having probably been toward E.

Flute-casts (Crowell 1955, pl. 2, fig. 3, Kelling and Walton 1956, fig. 2, p 484, Prentice 1960, pl. 1, flow markings of Rich 1950, fig. 8, p. 727), were at Skillinge found only on a loose slab (fig. 10A), where they run parallel to the groove-casts. The current that eroded the substratum (and deposited the silt above?, cf. Prentice 1960, p. 220, Cummins 1959, p. 176) ran in the direction from the marked-off, narrow, rounded end of the cast toward the end where the cast widens out, gets smooth, and dies away. Flute-casts provide the easiest criterion as well as one of the safest ones, for establishing the direction of sediment transportation during the deposition of the Colonus Shale (fig. 11, arrows).

Current-bedding is not well developed at Skillinge, but can be easily studied in the thin beds of calcareous mudstone that occur in most of the outcrops of Colonus Shale inspected by me.

SEDIMENTARY STRUCTURES IN OTHER OUTCROPS

Ö. Tommarp (9, fig. 1). Colonus Shale of a facies that is in every respect identical with that at Skillinge appears in excellent outcrops along the river Järrestadsån, particularly at the locality 7: XXI of Moberg 1910, p. 42 (87). This outcrop is situated about 1 500 meters E of the church of Ö. Tommarp. Massive beds of sandy, micaceous siltstone alternate with more shaly strata. Load-casts, small "longitudinal ripple-load-casts", groove-casts, and flute-casts are of common occurrence in all parts of this outcrop. The current direction indicated by two flute-casts is S 60° E. Load-casts are as a rule overturned toward E.

Örup (12, fig. 1). Light grey Colonus Shale with calcareous current-bedded mudstones occurs at both ends of the rifle-range of Örup, about 2 500 meters S of the railway station of Tomelilla in SE Scania. The outcrop at the targets contains abundant graptolites (*Monograptus colonus* (Barr.) (sparse), *M. nilssoni* (Barr.) (very common), *M. bohemicus* (Barr.) (sparse), cf. *Spinograptus spinosus* (Wood)). Flute-casts found at both outcrops indicate flow toward S 40—55° E.

Tolånga (3, fig. 1). On the S side of the river Tolångaån, little more than 500 meters SW of the church of Tolånga, the light grey, almost barren Colonus Shale contains several, a few centimeters thick, beds of calcareous mudstone that in part are current-bedded and, particularly in the E part of the outcrop, show groove-casts and flute-casts on their lower sides. The two flute-cast observations that could be made in different beds indicate flow toward N 75° E and N 82° E. Groove-casts have directions ranging from N 52° E to N 80° E.

Borstbäcken (4, fig. 1). On a very rapid survey of this extensive series of outcrops, groove-casts striking N 45° W were found about 700 meters SW of Norrigehus. The place is not easily accessible, but merits a thorough investigation.

Harlösa (5, fig. 1). A small outcrop (B, fig. 6) in the brook about 175 meters E of the fold locality contained flute-casts indicating flow toward S 60° E.

Sireköpinge (7, fig. 1). Colonus Shale outcrops in a few places along the brook flowing from NE toward the church of Sireköpinge. E of the farm Norrlycke, in the tributary that flows from the village Brödåkra, there are a few minor outcrops of current-bedded somewhat calcareous Colonus Shale. In addition to the current-bedding there are flute-casts that indicate flow toward S 15° E.

CONCLUSIONS ON SEDIMENTARY STRUCTURES

This probing survey, departing from the study of the temporary exposures at Skillinge, indicates that currents during the deposition of the Lower Ludlovian Colonus Shale in Scania flowed from NW—W toward SE—E, and that the source of the Colonus Shale sediments (800 m thick according to an estimate by Törnebohm and Hennig, 1904) should have been in NW—W.

It is interesting to note in this connection that the boring Leba in Pomerania, 200 km ESE of Scania, ended in Colonus Shale, of which it penetrated 560 m (Dahlgrün and Seitz 1943), whereas W (—WSW) of Scania, Silurian strata as high as the Colonus Shale are missing, according to the boring Slagelse no. 1 on Zealand (Larsen and Buch 1960). The Colonus Shale of Leba is mainly horizontal, although disturbed in some parts of the core, whereas the Cambro-Silurian of Slagelse is inclined at 20°, and is followed upward by horizontal Lower Permian. The earlier Silurian strata of Slagelse are of course likely to have been elevated after the close of the Silurian, but there would in any case have been an elevated area subjected to erosion somewhere in this direction during the deposition of the Colonus Shale.

Kuenen (1957) has suggested that the main source of sediments frequently is at one of the ends of troughs of a geosynclinal type and that sediment transport runs parallel to the trough. This hypothesis has been more or less confirmed for certain Caledonian geosynclinal tracts in NW Europe (Kelling 1958, Cummins 1959, Wood and Smith 1959). One may perhaps suggest that it also applies to the Colonus Shale trough, which would in that case have extended in NW—SE or perhaps W—E, south of the contemporary shelf (and shelf-edge?) deposits of the central Baltic.

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Bentonit och fjärrkonnektion

Anmärkningar med anledning av N. Spjeldnæs' uppsats »Silurian bentonites from Gotland»

Av

Bertil Wærn

Abstract: Bentonite and long-distance correlation. Comments on N. Spjeldnæs's paper »Silurian bentonites from Gotland».

In his paper »Silurian bentonites from Gotland» N. Spjeldnæs presents a long-distance correlation of 4 bentonite layers observed in the Lower Visby Marl with a number of bentonite layers in the section of Kullatorp at Kinnekulle in Västergötland. This correlation is rejected for the following reasons:

a. On the basis of reliable faunistic evidence the Lower Visby Marl has to be correlated with the zone with *Monograptus spiralis* (= zone 25 according to Elles and Wood), while the portions referred to by Spjeldnæs in the section of Kullatorp belong to the zones with *M. turriculatus* and *M. discus* (= zones 22—24 according to Elles and Wood).

b. With our still rather incomplete knowledge of the numerous bentonite layers that since some years have been reported in ever increasing numbers from Scandinavia, a long-distance correlation based upon such insignificant material alone must be considered premature.

I en uppsats betitlad »Silurian bentonites from Gotland, Sweden» i denna tidskrift, Bd 81, H. 4, s. 582—587, beskriver Nils Spjeldnæs, Oslo, ett antal bentonitnivåer inom de äldsta blottade silurlagren i kustklinten på Gotlands nordvästra kust. Uppsatsens huvuddel ägnas åt en redogörelse för förekomstsättet och åt att visa huru bentonitlagren, vilka äro att uppfatta som isokrona lednivåer med vidsträckt utbredning, kunna tjäna att konnektera lager, där en gränsdragning mellan stratigrafiska avdelningar synes ha skett mera efter en vid olika tid skeende faciesförändring än efter verklig samtidighet. Detta är intressanta nya rön och understryker än en gång den hjälp man kan ha av detaljerat noterade bentonithorisonter, när man söker åstadkomma stratigrafiska konnektioner.

När förf. emellertid på sid. 586—587 försöker sig på en fjärrkonnektion med de av mig (1948)[1] beskrivna bentonitnivåerna i Kullatorpsprofilen, Kinnekulle, och därvid daterar de äldsta Gotlandslagren till att vara samtidiga med lägre delar av Upper Llandovery (zoner med resp. *Monograptus turriculatus* och *M. discus*), måste jag anmäla avvikande mening. Datering med hjälp av fossila faunor stöder ej författarens tolkning till den utsträckning han synes tro. Dessutom lämnar konnekteringen av hans gotländska bentonitnivåer med just de västgötska alltför stort spelrum åt frågan, varför ej andra i litteraturen nämnda nivåer kommit i fråga. (För att ej ha tagit hänsyn till förekomsten av talrika, ännu opublicerade nivåer kan ju förf. icke lastas, men en försiktigare man än han kanske skulle räknat med möjligheten att sådana kunde existera.)

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[1] För den citerade litteraturen hänvisas till Hede 1942, Wærn 1948 och Spjeldnæes 1959.

De av Spjeldnæs beskrivna bentonitnivåerna äro belägna i Undre Visby märgelsten. Denna är närmast att korrelera med zonen med *M. spiralis* (= Zone 25 enl. Elles & Wood). För detta talar främst förekomsten av *Stricklandinia lirata* (J. de C. Sowerby) f. *typica* och *M. spiralis* Gein. Den förra är ett ledfossil för Undre Visby märgelsten. Dessutom omtalas den från *spiralis*-zonen vid Styggforsen i Dalarna av Törnquist (1883, s. 25).[1] Enligt St. Joseph (1935, s. 420—421) är denna form »restricted in Great Britain and Scandinavia to a constant narrow horizon at the top of the Upper Llandovery, for which it forms a useful and reliable zone fossil».

Monograptus spiralis, som av Hedström (1923, s. 195) omtalas från Övre Visby märgelsten, är i Sverige ej funnen utanför zonen med samma namn. Laursen (1940)[2] anför arten från Bornholm i zonerna med *Cyrtograptus grayae* och med *M. spiralis.* Emellertid uppger han den på flera nivåer förekomma tillsammans med *M. discus* Tqt, en art som annorstädes är inskränkt till zonerna med *M. crispus* (23) och *M. griestoniensis* (24). Vid granskning av mitt insamlade material från Laursens fossillokaler i Öleaa har jag emellertid kunnat fastställa, att den art, som förekommer samtidigt med *M. discus,* är *M. (Spirograptus) tullbergi* (Bouček) och icke *M. spiralis,* som uppträder först högre upp i lagerserien. Av detta torde följa att hela Laursens zon med *Cyrt. grayae* och större delen av hans zon med *M. spiralis* bör korreleras med de brittiska zonerna med *M. crispus* och *M. griestoniensis.* Enligt Elles & Wood (1901—1918) förekommer *M. spiralis* i Storbritannien från zonen med *M. turriculatus* (22) till zonen m. *M. crenulatus* (25), och denna uppgift citeras av Hede (1942, s. 9—11). Det vore i detta sammanhang en angelägen uppgift att få angivelserna om artens stratigrafiskt äldre förekomster i Storbritannien ånyo granskade.

Styrkan av dessa ovan angivna argument — som tidigare till väsentlig del anförts av Hede (1942) och Thorslund (1949) — för en korrelering mellan Undre Visby märgelsten och zonen med *Monograptus spiralis* (= brittiska zonen 25 med *M. crenulatus*), synes egendomligt nog ha undgått Spjeldnæs.

Jag vill så ge en hastig överblick över bentonithorisonter i Sveriges Llandovery. Thorslund (1948) rapporterar förekomsten i Undre Visby märgelsten och fäster uppmärksamheten på 4 bentonitlager vid Röstånga i Skåne från zonen med *Monograptus spiralis.* Samma år beskriver han (1948a) bentonit från zonen med *M. turriculatus* i Jämtland. Senare detta år kommo mina egna undersökningar från Kinnekulle i tryck (Wærn 1948). Jag omtalar där ett antal nivåer i Kullatorpskärnan inom zonerna med *M. sedgwicki, M. turriculatus* och *M. discus*. Samtidigt omnämner jag liknande lager från en borrning i Östergötland (s. 463) samt en säker och ett par sannolika bentonithorisonter från *M. spiralis*zonen på Kinnekulle ovan borrprofilen (s. 447).

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[1] Sveriges geol. unders. Stockholm, Ser. C, N:r 57.
[2] Danmarks geol. unders., Köbenhavn, 2 Raekke, N:r 64.

Dessutom kan jag preliminärt meddela, att i profiler från Dalarnas graptolitförande Llandovery, som jag f. n. bearbetar, ha från zonen m. *Monograptus revolutus* i Lower Llandovery till översta Llandovery närmare ett 40-tal nivåer kunnat urskiljas, därav 25 st. inom *M. turriculatus-* och *M. discus*zonerna.

Av det ovan anförde torde framgå, att bentonithorisonterna i Baltoskandias silur (och även i ordovicium) ännu äro blott ofullständigt kända till utbredning och antal, vilket ej bör förvåna, då de ej uppmärksammades förrän 1945.

Med hänsyn till vad som ovan anförts synes Spjeldnæs' fjärrkonnektion vara utförd på otillräckligt känt iakttagelsematerial och med paleontologiska belägg dels hårdraget tolkade, dels negligerade och torde därför ej ha utsikter att räknas som bestående.

Även i sin avslutande utblick, där Spjeldnæs vill finna tidigare vulkanism i norra än i södra Nordeuropa, pressar han det tillgängliga iakttagelsematerialet väl hårt. Att bentonitnivåer ännu ej publicerats från en viss nivå eller trakt får i nuvarande läge ej uttydas så att de skulle saknas där. I Jämtland känna vi ännu ej säkert daterade siluriska lager yngre än den brittiska zonen 24 och därmed daterbara bentonitlager. I Dalarna har jag mig bekant bentonit mellan zonerna 18 och 26. I Västergötland (Wærn 1948) och på Gotland (Spjeldnæs' feldaterade skikt) finnes bentonit åtminstone till zonen 25. Om frekvensen av bentonitlager i Skånes äldre Llandovery veta vi ännu intet. Vad vi däremot våga hävda är att askregnen över det Baltoskandiska området vid tiden för sedimentationen av lagren i och omkring *M. turriculatus*zonen (zon 22) varit både täta och kraftiga, medan »vulkanismen inom västra Europa var livligast under det tidsavsnitt som svarar mot sen Valentian och tidig Wenlock» (Thorslund 1948a, s. 245).

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SVENSKA FÖRENINGEN FÖR LERFORSKNING

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OSTERMAN, J.: Views on the stability of clay slopes 346
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Views on the Stability of Clay Slopes

By

JUSTUS OSTERMAN

Swedish Geotechnical Institute, Stockholm

Abstract. Some aspects are presented on the judgement of the stability of clay slopes in Sweden.

Among other things, the structural changes of soil elements, exposed to shear, and their influence on strength are discussed.

The relation between the soil plasticity and the ratio between strength and overburden pressure is touched upon, and the influence of water pressure and seepage on the latter.

Further, the difference between the condition of equilibrium and that of stability is discussed.

Introduction

Since the author was asked to give a lecture on the stability of clay slopes, he has published a paper (Osterman 1960) on the strength of soft, plastic clays. Only a few points will be recalled here, necessary to follow the reasoning, as well as some explanatory distinctions. The discussion will be confined to Swedish saturated clays in a state close to normal consolidation, and with normal sensitivity.

When a clay consolidates under an overburden, the skeleton is exposed to overexertion causing settlements and creep, delayed by the time-consuming pore water flow.

The rate of flow in a certain clay is dependent on the pore water pressures, u, which can be measured by means of an ordinary piezometer and are thus gravitation parts of the soil water stresses.

During this course of events the clay will decrease in volume, with a consequent increase in cohesion and possibly also in frictional resistance capacity. In natural terrain the horizontal dimensions of the clay elements are mainly unchanged, and a shearing deformation occurs. In principle, the problem refers to a reorientation of the grains.

It may be mentioned in this connection that the shearing resistance of the clay skeleton can be affected by the loading operation, giving extra pore water overpressures. These excess pressures seem to decrease rather rapidly as indicated by some oedometer tests performed by Hansbo (1960), who considers it to be a thixotropic effect. He also points out a possible extra delay in the pore water flow from that calculated on the basis of Darcy's law.

However, we may still discuss matters on the assumptions of a period of mainly primary settlements with considerable loss in pore water overpressures (and some thixotropic effects) and a period of mainly secondary creep with rather small or stationary pore pressures.

We can calculate an angle of apparent friction required from the formula

$$\tan \Phi = \frac{\sigma'_1 - \sigma'_3}{2\sqrt{\sigma'_1 \cdot \sigma'_3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where σ'_1 = major principal effective stress = $\sigma_1 - u$
σ'_3 = minor » » » = $\sigma_3 - u$

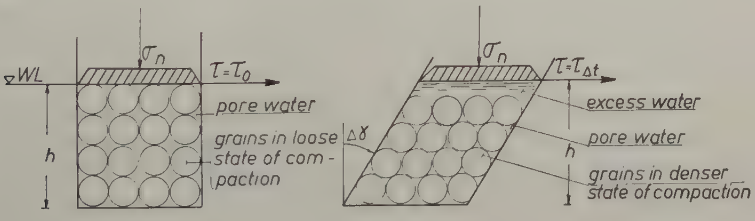
In the case of consolidated equilibrium this angle is called Φ_{ce} by Tschebotarioff (1957) and others.

The strengthening effect of the secondary settlement was discussed in the paper of the present author. From that effect it follows that a small increment of load may be added before considerable primary settlements will begin. That may be the cause of the similar effects which have been found and discussed by Leonards and Ramiah (1960).

At failure the clay can resist greater stresses than at consolidated equilibrium, and the question of creep is therefore important, especially in the case of high plasticity clays.

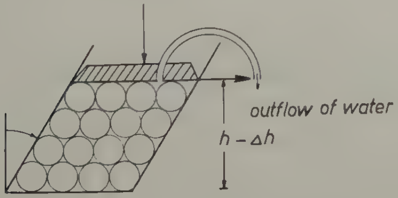
Drained and Undrained Strength

When discussing the shearing resistance of soils, the expressions "drained" strength and "undrained" strength are often used. The meaning of the terms will be clear from a demonstration of the function of the simple shear model given in Fig. 1.


σn
WL
T=T0
pore water
grains in loose state of compaction
h
σn
T=TΔt
Δγ
excess water
pore water
h
grains in denser state of compaction

a) Container with loosely filled grains and water

b) Undrained shear



c) Drained shear

Fig. 1. Model showing the principles of undrained and drained shear in the case of a loose granular mass.

Fig. 1a shows a swayable box filled with saturated soil with a grain skeleton in a loose state of density. The soil is exposed to normal load, taken up by intergranular stresses, and thereafter the box is sheared.

In Fig. 1b is shown how the soil structure will then break down, and how the load after the shearing will be carried by pore water pressures in the case of no drainage. For the granular material the resistance to shear will of course vanish. One may perhaps talk about a kind of negative inner dilatancy.

Fig. 1c shows how the load will still be carried by intergranular stresses in the case of immediate drainage, and it is obvious that there will be a resistance to shear. The volume will decrease and thus there will also be negative outer dilatancy.

If, on the other hand, the grains were originally densely packed, and the soil structure swelled when sheared, a decrease in pore water pressure would, in the case of no drainage, influence the intergranular stresses.

Thus the undrained shear strength may be lower or higher than the drained strength. In the case of the grains in the so-called "critical" state of density, cf. Casagrande (1936), no volume change will occur, and the resistance to shear will be almost unaffected by dilatancy effects.

The above-mentioned model can be used for a simple description of the behaviour of frictional soil exposed to shear. Sand layers can often be found in the clay slopes. When the intergranular stresses are moderate, due to artesian pressures for instance, the frictional resistance to shear failure may be low. If the soil density is loose, a failure will occur quickly.

Recently, Bjerrum a. Simons (1960) have given values of the angle of apparent friction in fine sand and silt down to 10-11°.

Roscoe, Schofield and Wroth (1958) state that the yielding of a clay sample defines a loading path in the coordinate space, defined by the effective stress, σ'_n, normal to the failure surface, the void ratio, e, and the shear stress τ_f in the failure surface, and that the ends of the paths lie at a unique "critical void ratio line". Moreover, it is said that in the tests on overconsolidated samples the positive change (Δu) in pore water pressure is less than in tests on normally consolidated samples. For heavily overconsolidated samples, Δu may become negative. In the paper an overconsolidation ratio line at the critical state is discussed. All samples on the "wet" side will contract in drained tests, or show a positive pore pressure change in undrained tests; whereas all those on the "dry" side will dilate or develop a negative pore pressure change. In this connection the authors refer to earlier papers by Hvorslev and Haefeli.

Attention is drawn to the circumstances just mentioned, because of its importance when judging the behaviour of Swedish clays, most of which are on the wet side, but clays on the dry side might be found in riversides, for instance. That part of the shearing resistance which is due to friction will decrease when the value of u increases.

As appears, the low plasticity materials will give strength results which differ very much in the case of drained tests from that of undrained tests. Swedish clays, however, are rather plastic as can be seen from the plasticity chart,

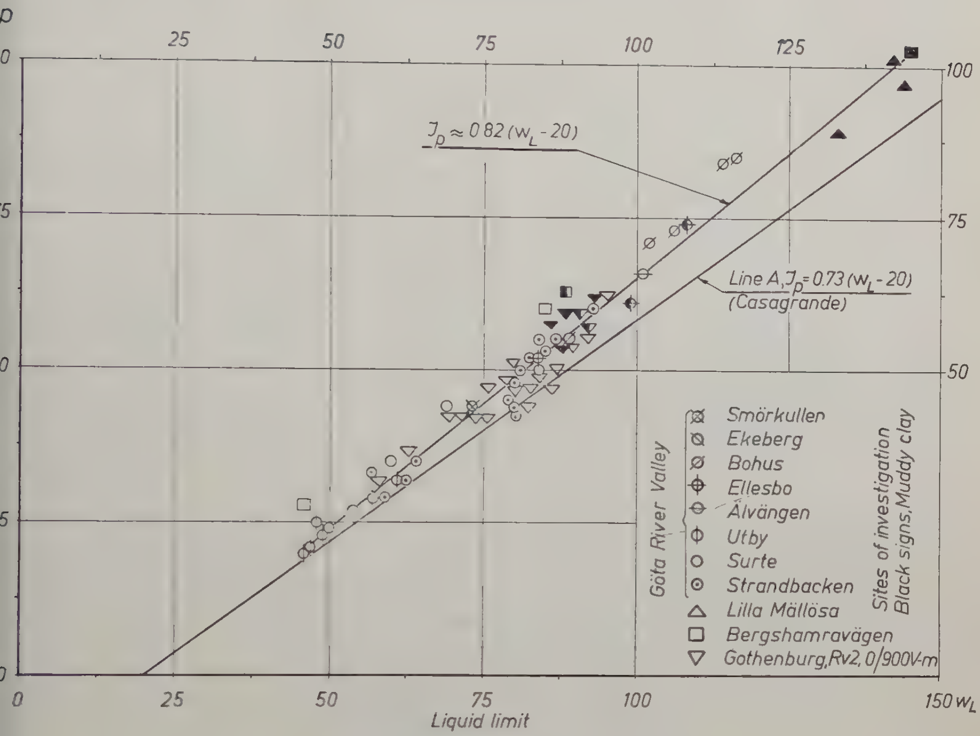


Fig. 2. Plasticity chart for some Swedish clays.

drawn according to Casagrande's principles, shown in Fig. 2, which demonstrates a relation between liquid limit w_L and plasticity index I_p for some clays, tested recently.

Results of Simple Strength Tests

During a drained standard test in a shear box, consolidation occurs and the apparent angle of friction made use of at failure (in the case of normal consolidation), will instead of from Eq. (1), be calculated from the formula

$$\tan \Phi_d = \frac{\tau_f}{\sigma'_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where τ_f = shearing resistance in failure surface

σ'_n = effective normal pressure on failure surface

as the principal stresses are not exactly known.

Fig. 3 shows the results of a number of drained shear box tests in relation to the plasticity index. Table I shows some additional data of the test specimens, volume weight γ tons/m^3, water content w in percentage of dry weight in natural state, and plastic limit w_P. Owing to the difficulties of making the

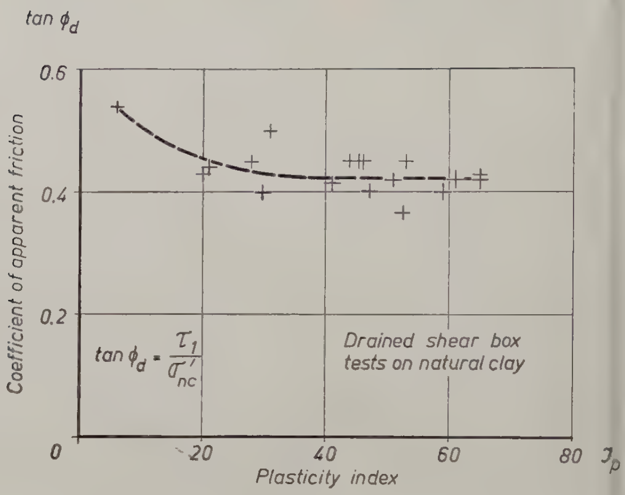


Fig. 3. Apparent angle of shearing resistance plotted against plasticity index, in normally consolidated drained shear-box tests.

tests perfectly drained and to wait for the final consolidation, the Φ_d-values may be a little too low.

During an undrained standard test in the shear box the consolidation is due to the normal pressure and no further loss of water will occur. The apparent angle at failure will be calculated from the formula

$$\tan \Phi_{cu} = \frac{\tau_f}{\sigma_{nc}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where σ_{nc} = total normal pressure on failure surface = initial consolidation pressure

It must be mentioned that this test applies to a special case of loading.

Table I. Data of slow shear-box tests, performed in the SGI-apparatus

Identification No.	Depth m	Volume weight t/m³	w	w_L	w_p	I_p	$\tan \Phi_d$	Soil classification
1403 K 6392		1.75	39	57	27	30	0.40	Black a. grey silty clay, seams of sandy silt, bands of iron sulphide
4745 K 6392		1.74	45	57	36	21	0.44	Dark-grey silty sulphide clay
4474 K 6392		1.74	42	55	35	20	0.43	Dark-grey sandy silty sulphide coarse clay
4037 K 6392		1.62	61	88	37	51	0.42	Dark-grey muddy silty clay
7652 K 6392		2.07	22	26	20	6	0.54	Grey varved silt, seams of fine sands
1873 K 5517, Bh 18	14					65	0.425	
5940 K 5517, Bh 18	28					41	0.415	
1235 K 5314 Ekeberg	20.5	1.65	62	90	31	59	0.40	Grey clay with shells
1147 K 7068 Älvängen	10	1.49	94	99	38	61	0.42	Blue-grey muddy clay, bands of iron sulphide

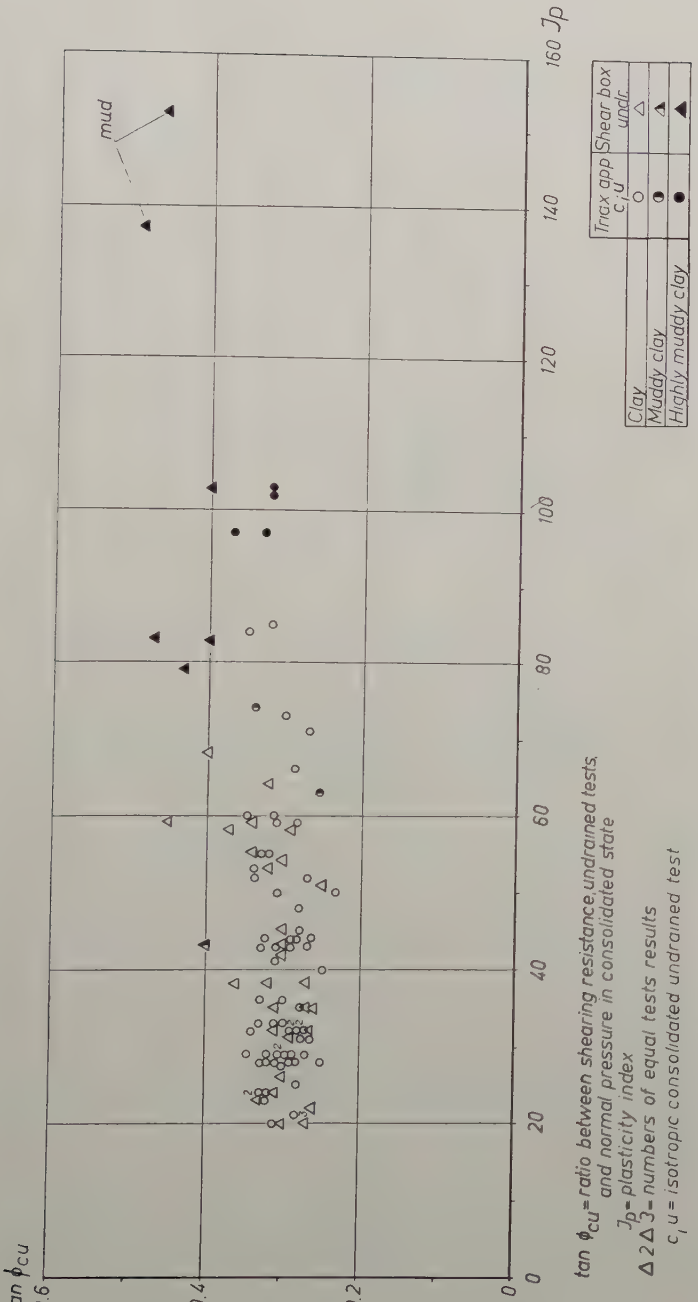


Fig. 4. Apparent angle of shearing resistance plotted against plasticity index, in normally consolidated undrained tests.

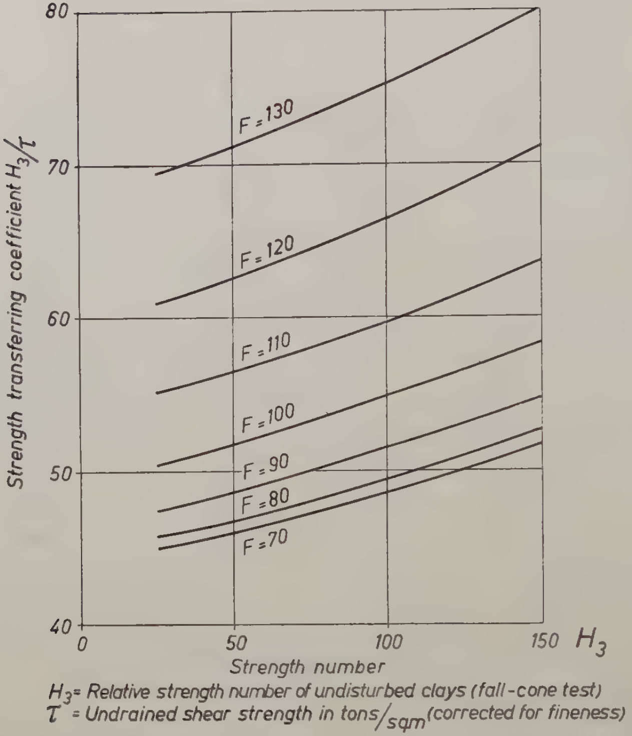


Fig. 5. Diagram showing the value H_3/τ_f as a function of strength number H_3 (see also the text) and fineness number F in the case of the fall-cone test according to J. Olsson.

Fig. 4 shows the results of a number of undrained shear box tests in relation to the plasticity index. In the figure a number of triaxial results are also plotted. For reasons discussed below these results must be regarded with some care.

Owing to the difficulties of making the tests perfectly undrained and quickly, the Φ_{cu}-values may often be too high at small values of I_p.

In the laboratory the undrained strength can also be measured by use of the fall-cone test, a very careful study of which was made by the inventors, the Geotechnical Commission of the Swedish State Railways, 1914—1922 (see Final Report 1922). Terzaghi (1927) introduced a theoretical attempt for the interpretation of the fall-cone test.

On the suggestion of the present author ultra rapid pictures were taken of the motion of the cones and the results were worked up. A comparison was made between the fall-cone test and the vane test results by Hansbo (1957), who used a more precise attempt. The investigation showed that both tests were of similar character, and that an interpretation from the one test to the other did not necessitate to account for the organic content.

In the case of the fall-cone test, J. Olsson has calculated a strength correction for the clay fineness necessary. Fig. 5 shows a diagram of the reduction

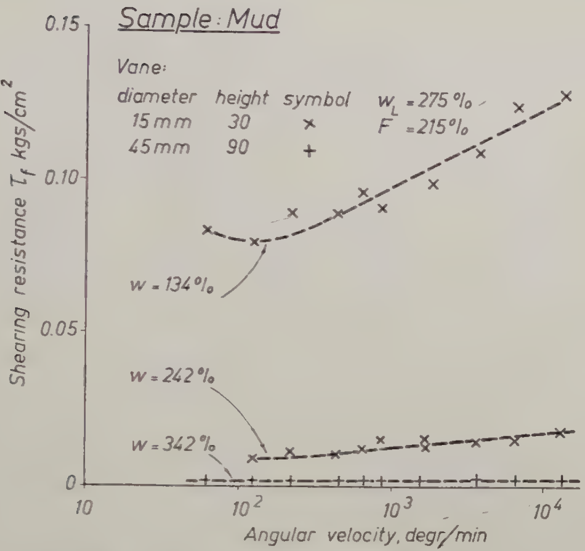


Fig. 6. Diagram showing the shearing resistance of mud as a function of the angular velocity of the laboratory vane.

mentioned as a function of the fineness number which he has sketched. In this connection the fineness number *F* can be identified with the Atterberg percussion liquid limit. (The *H*-number of any clay is the weight in gm. of the 60° cone, which is given a penetration of 10 mm, when dropped from the surface of the sample, divided by 6 gm. thus giving, in the case of 60 gm.-60° cone, an *H*-number equal to 10. Index 3 refers to undisturbed samples.)

The shearing resistance of a remoulded clay can also be determined by the fall-cone test or by the laboratory vane test. In the latter case it is possible to observe the influence of the shearing velocity.

Fig. 6 shows the shearing resistance of a remoulded mud at varying angular velocity (in log-scale) of the laboratory vane. The disturbing effects in disperged systems, when the viscosity is decreasing with increasing velocity, are normally due to coupling on the molecular scale between the dispersed phase and the solvent in addition to orientation[1] effects of anisotropic particles and straightening of coiled threads, etc. As can be seen from the figure the apparent viscosity decreases when the shearing velocity increases, and some characteristics, similar to those just mentioned, seem to influence the behaviour of the mud.

Owing to similar phenomena it may be necessary to reduce strength results obtained by means of quick testing, especially at high percentages of organic matter or high periphery velocity, also in the case of vane tests. Thus, the size of the vane can have an influence.

Fig. 7 shows the ratio between uncorrected vane strength *c* and overburden

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[1] A diagrammatic representation of the build up of coarse grains in a surrounding colloidal matrix at failure is sketched by Trollope and Chan (1960).

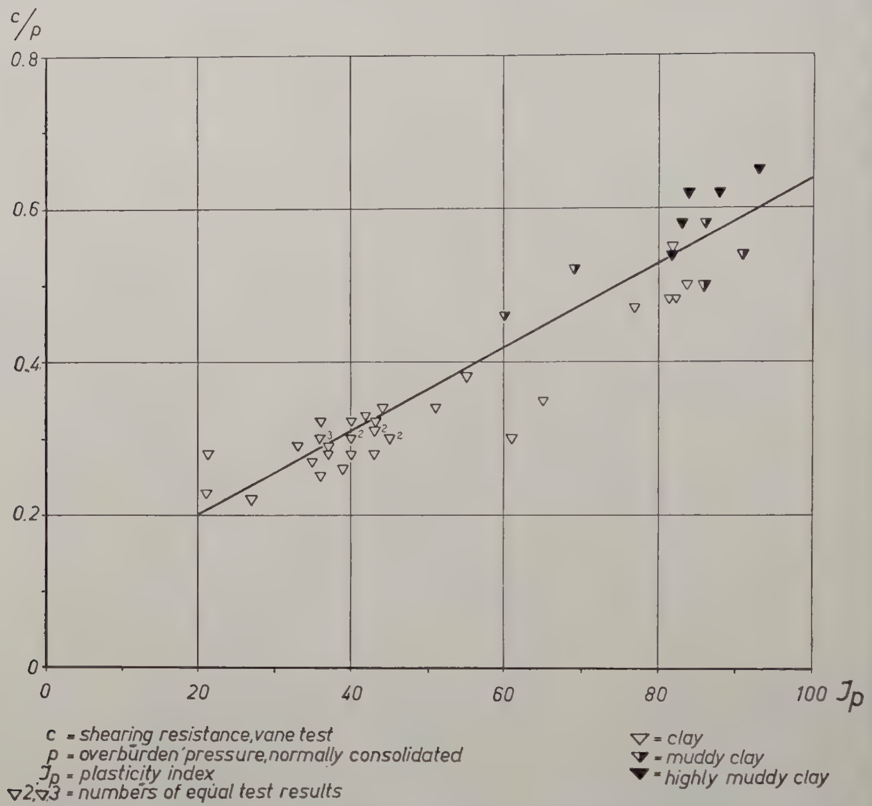


Fig. 7. Ratio between shearing resistance c and overburden consolidation) pressure p as a function of the plasticity index.

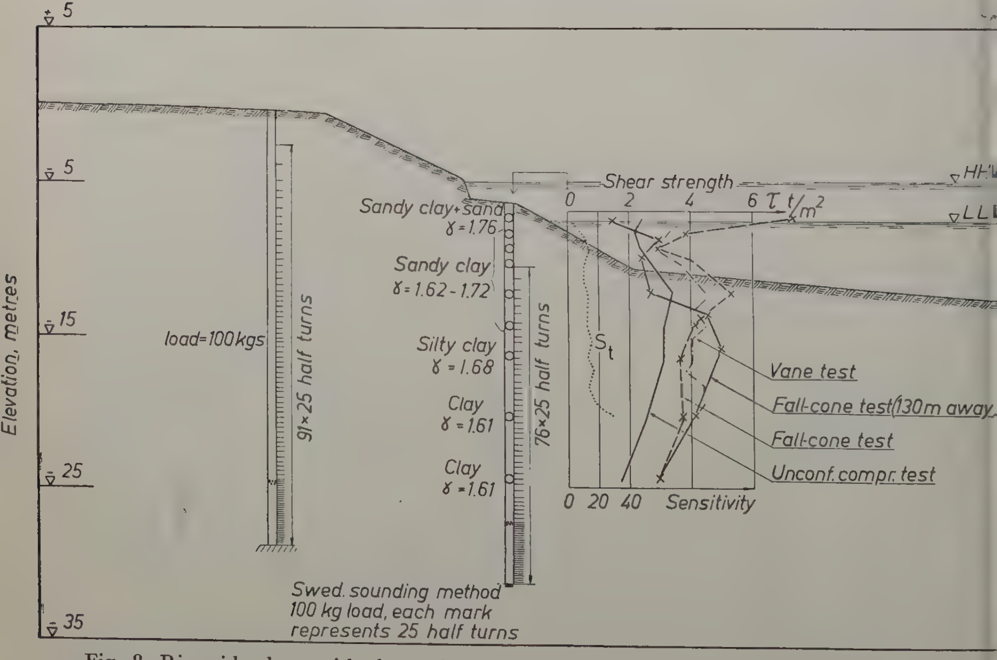


Fig. 8. Riverside slope with decreasing shear strength at greater depths in a tested profile.

pressure p as a function of the plasticity index I_{P}. The reduction just named should increase with increasing index.

The organic matter plays an important rôle for the strength. Figs. 4 and 7 show some earlier results, here revised with regard to organic content. The clays have been called muddy, when the loss of ignition has been round about 2.5 as percent of dry weight, or more. Also the type of mineral is important, see for instance Lambe et al. (1960).

Another problem of importance is the question of the swelling of the clay, due to suction, in Sweden mainly related to decrease in effective stresses. This suction effect may break the part of the cohesion which depends on overconsolidation.

In Swedish clays of low permeability this process seems to take a very long time. Old parts of a dry crust have been found which have lain under water for thousands of years and which are still very hard (compare the Final Report of the Geotechnical Commission of the Swedish State Railways).

On the other hand, at a test area at Väsby near Stockholm, where, as a consequence of the loading, water percolates the crust, the strength of it seems to decrease. In the valley of the Göta River in south-western Sweden

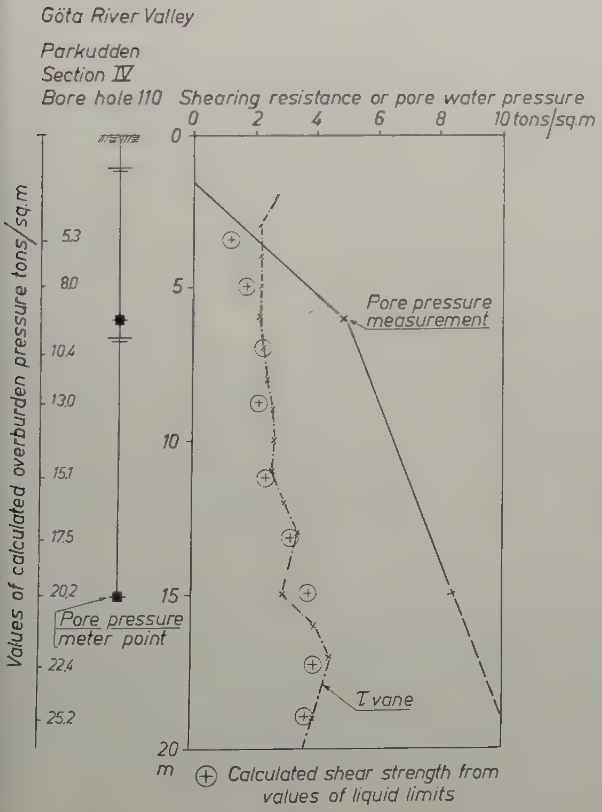


Fig. 9. Profile where the pore water pressures are increasing at a lower rate than the change in depth.

one often finds water under artesian pressure, especially in and around sand layers. This water flows to the river through the clay and sometimes in an upward direction. Obviously, this may explain some of the low strength results which are measured close to such permeable layers.

Fig. 8 may indicate such a phenomenon, where the undrained strength results obtained with various methods are lower at greater depth.

Fig. 9 on the other hand shows a case, where the pore water pressures are rather low in the lower part of the profile investigated, seemingly indicating a pore water flow downwards. The strength distribution is measured and calculated, the results of both methods being similar, indicating rather stationary flow conditions.

Bases of Strength Assumptions

In other countries, the modified Coulomb formula is often used for clay. It is written

$$\tau_f = c' + (\sigma_n - u) \tan \Phi' \quad \dots\dots \quad (4)$$

where c' = apparent cohesion

Φ' = angle of apparent friction

σ_n = total pressure normal to the failure surface

At normally consolidated clays the origin values of c' can usually be omitted, and it should be possible to write

$$\tan \Phi' = \frac{\tau_f}{\sigma'_n} \quad \dots\dots \quad (5)$$

In the drained case this formula is equal to Eq. (2). The Coulomb formula can thus be used at the first loading.

In the interpretation of the undrained triaxial test, however, some complications will arise. Suppose for instance that the test sample is consolidated for an all-around pressure σ_c. If the failure is caused by increasing the axial pressure by an amount $\Delta\sigma_1$ and, which may often be assumed, if the pore water pressure increases by the same amount, the normal pressure σ'_n will decrease, giving rise to difficulties of interpretation. If the state of consolidation should be dominated solely by σ'_1 this interpretation should give the same results as the drained shear-box test, in which σ'_1 is also higher than σ'_n.

The same problem will arise if the failure is performed in decreasing σ_3, and with zero pore water overpressures, $\Delta u = 0$.

Fig. 10 shows the results of a number of undrained triaxial tests in relation to the plasticity index (examined strictly after the modified Coulomb formula, corrected for measured pore water pressures, see Fig. 11a), which differ, however, very much from the Φ_d-values of the shear box. Also the relationship is rather strange and the scattering of results is high.

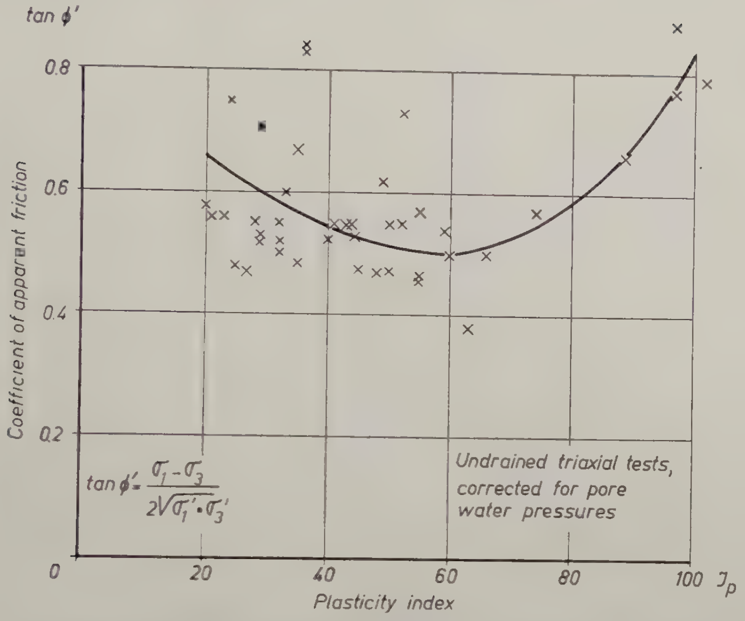


Fig. 10. Apparent angle of shearing resistance plotted against plasticity index, in undrained short-term triaxial tests, using effective stresses.

There may be many reasons for that. One is the all-around consolidation and the time effect, which must be of influence. Another lies in the pore water pressures set up, and also the manner of interpretation. Besides, the formula may not fit.

We will try the Skempton (1954) formula for pore water pressures on some extensively tested soils

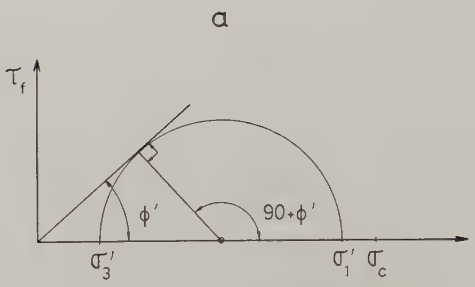
$$\Delta u = B\,[\Delta\sigma_3 + A\,(\Delta\sigma_1 - \Delta\sigma_3)] \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

where $\Delta\sigma$ = increment of stress
A = constant B = constant

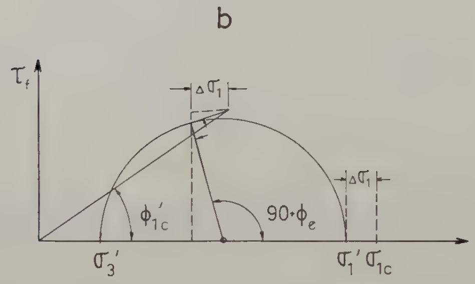
The following results are obtained. Firstly, in the case of performing the triaxial test by decreasing σ_3, keeping $\Delta u = 0$ at the same time, one gets

$$A = -\frac{\Delta\sigma_3}{\Delta\sigma_1 - \Delta\sigma_3} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6a)$$

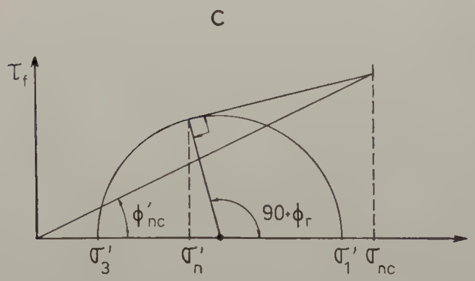
This case gives in some normal consolidated cases the following A-values. (Some additional data of the test specimens are given in Table II, the isotropic consolidation pressure σ_c, the major principal stress σ'_{1f} at failure, minor principal stress σ'_{3f} at failure, etc.)



$$\tan\phi' = \frac{\sigma_1 - \sigma_3}{2\sqrt{\sigma_1' \cdot \sigma_3'}}$$



$$\tan\phi_{1c}' = \frac{(\sigma_1-\sigma_3)\cos\phi_e + 2(\sigma_{1c}-\sigma_1')\tan\phi_e}{2\sigma_{1c}-(\sigma_1-\sigma_3)(1+\sin\phi_e)}$$



$$\tan\phi_{nc}' = \frac{(\sigma_1-\sigma_3)\cos\phi_r + 2\sigma_{nc}\tan\phi_r - [\sigma_1'+\sigma_3'-(\sigma_1-\sigma_3)\sin\phi_r]\tan\phi_r}{2\sigma_{nc}}$$

Fig. 11. Explanatory figure showing different methods of interpreting triaxial tests. In method *a* one also may find solutions with other tangent or secant points. In method *b* (when used strictly) one corrects for volume changes due to $\Delta\sigma_1$.

Lilla Mellösa	Test No. 1 013	A = 1.01
Surte	1 830	1.15
	2 319	1.11
	4 148	1.03
	6 694	0.94
Strandbacken	25D	1.32
	25E	1.21

Thus $A = 1.1$ on an average. Testing the same soils with increasing σ, and reading the Δu-values, one gets

Lilla Mellösa	Test No. 1 024	B = 1.01
	1 054	1.07
	1 058	1.08

Table II. Data of triaxial tests with reduction of stresses and keeping the pore water overpressure Δu = 0, (performed in the apparatus, type NGI)

dentification No.	Depth m	Volume weight t/m³	w%	w_L	w_p	I_p	σ_0 kg/cm²	σ_{3f}	σ_{1f}	tan Φ'	tan Φ'_{1e}	tan Φ'_{ne}	Soil classification
13 F 12	3 5	1.43	112	133	44	89	3.0	0.86	2.98	0.662	0.656	0.425	Dark-grey clayey nekron mud
19 K 5314	7.5	1.66	55	60	25	35	1.15	0.30	1.06	0.67	0.60	0.475	Grey clay
30 K 5314	7.5	1.59	58	69	25	44	3.10	1.0	2.82	0.55	0.49	0.42	Grey clay
94 K 5314	10	1.70	53	54	27	27	4.15	1.76	4.32	0.47	0.475	0.425	Grey clay
48 K 5314	10	1.70	45	50	26	24	2.15	0.75	2.11	0.54	0.53	0.47	Grey clay
D K 5314	20.5	1.59	70	87	32	55	4.8	1.65	4.03	0.46	0.405	0.355	Grey clay, slight sulphide bands
E K 5314	20.5	1.59	70	87	32	55	6.8	2.48	6.06	0.46	0.425	0.37	Grey clay, slight sulphide bands

Other tests have shown that A and B under certain conditions (especially at overconsolidation) vary more than given above. The assumption of the pore pressure increments being the same as the stress increments is thus not in strict accordance to reality.

Nowadays, in theoretical connections, the Hvorslev (1937) formula of shear strength is often used

$$\tau_f = c_e + (\sigma_n - u) \tan \Phi_e \quad \dots\dots\dots\dots\dots \quad (7)$$

where c_e = »true» cohesion
Φ_e = angle of »true» friction

In this formula, one has

$$c_e = \varkappa \cdot p_e \quad \dots\dots\dots\dots\dots\dots\dots\dots \quad (7a)$$

where $\varkappa$ = coefficient for working cohesion
p_e = equivalent consolidation pressure (belonging to void ratio at failure).

The pressure p_e is referred to the vertical pressure p_1 in the oedometer test in the following way

$$p_e = p_1 \cdot \mathrm{e}^{B'(e_1 - e} \quad \dots\dots\dots\dots\dots\dots\dots \quad (7b)$$

where e = void ratio.
e = 2.718 . . .

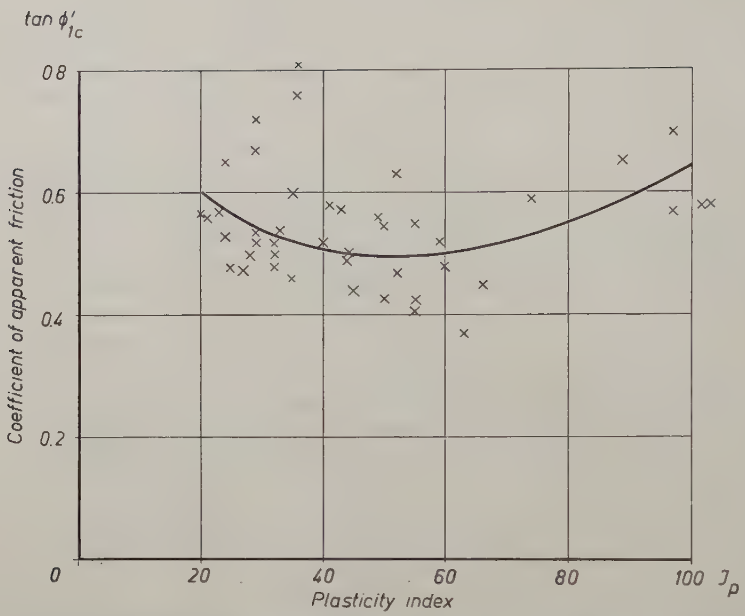


Fig. 12. Apparent angle of shearing resistance plotted against plasticity index, in undrained short-term triaxial tests, using effective stresses but corrected for changed σ'_1-stress.

The problem of the shear strength taken up from the Hvorslev formula is dealt with in the above-mentioned paper of Roscoe et al. as a problem in the space, the effective stress σ' and the void ratio e at failure being two of the axes.

It can be discussed whether the oedometer test in that connection really gives the proper values of the coefficients B' and $\varkappa$, which ought rather to be referred to a failure test. However, some proportionality is probable. Moreover, it seems reasonable that the particle shape and orientation, the quantity of organic matter, etc., should be of some importance.

Fig. 12 shows the same results as Fig. 10 but corrected for the differences between the major principal stress at consolidation and at failure, and for the direction of the failure surface (cf. Fig. 11b). This figure also shows a rather peculiar relationship between the coefficient of apparent friction, here called tan Φ'_{1c} and the plasticity index, and also some scattering of results.

Perhaps, the Hvorslev formula should not be used to interpret short-term tests. The problem of consolidation is obviously something more than the question of pore water pressures. One must discuss the cohesion due to secondary compression, etc.

Another formula in use is the Krey-Tiedemann formula (see Muhs 1957), which can be written

$$\tau_f = c_n + (\sigma_n - u) \tan \Phi_r \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

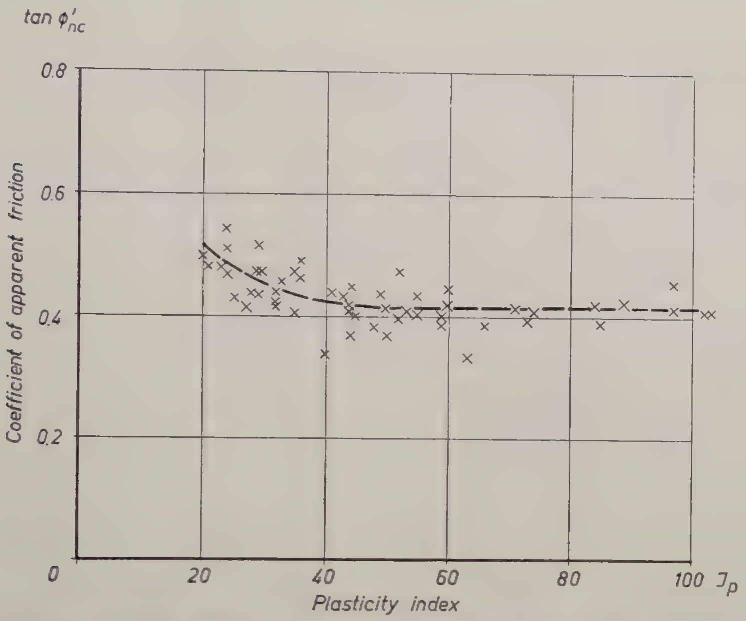


Fig. 13. Apparent angle of shearing resistance plotted against plasticity index, in undrained short-term triaxial tests, using effective stresses but corrected for changed σ'_n-stress.

where $c_n = \sigma_{nc} \cdot \tan \Phi_c$ .... (8a)

$\sigma_n - u$ = working pressure, normal to the failure surface
σ_{nc} = maximum working pressure, normal to the failure surface = = initial consolidation pressure
$\tan \Phi_c$ = coefficient of working cohesion
$\tan \Phi_r$ = » » » friction

The question of the accuracy of the Krey-Tiedemann formula is taken up by Hvorslev (1937), who points out the problem of swelling. This has also been mentioned by Muhs. In the case of clays of the Göta River Valley, however, the swelling is rather small.

Fig. 13 shows the same results as Figs. 10 and 12 but corrected for the differences between the initial consolidation pressure normal to the failure surface and the working pressure at failure, and for the direction of failure surface (cf. Fig. 11c). This figure, which also includes a few additional results, shows a rather smooth relationship between the coefficient of apparent friction, here called $\tan \Phi'_{nc}$, and the plasticity index.

At the latter calculation the present author has used a method suggested in his paper of 1960 to interpret the results of triaxial testing which, for the sake of simplicity, is graphic and approximate to be a simple complement to the usual pore water pressure correction in the Mohr circle version. Using the method just named the scattering of results of $\tan \Phi'_{nc}$ could be kept moderate for similar clays. When determining Φ'_{nc}, values of Φ_r are taken up from the

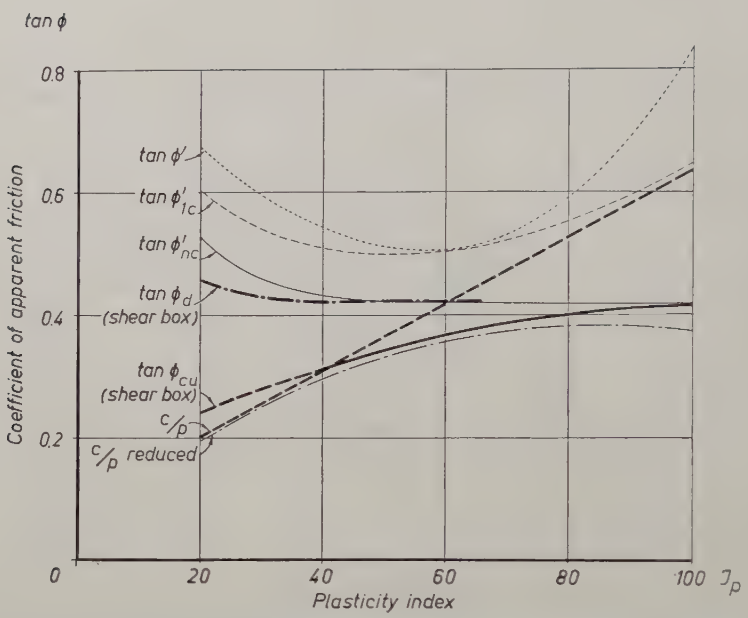


Fig. 14. Apparent angle of shearing resistance plotted against plasticity index, in normally consolidated tests or recalculated into effective stresses and normal consolidation, according to various interpreting methods.

Gibson (1953) diagram of Φ_r, which, however, should correspond to the Hvorslev angle Φ_e. The error thus introduced cannot be great.

The shear strength parameters were often earlier, when correction was made only for pore water pressure, derived in a way which will not hold true in the case of tests on Swedish clays. The most important reason for the deviations is probably prestresses, already mentioned by A. Casagrande and Wilson (1953), which may be allowed for according to the method of the above-mentioned paper of the present author.

These questions are most important when the consolidation pressures are higher than the actual pressures, the clay thus being in the range of overconsolidation. The isotropic consolidation in the laboratory may influence test results, a question touched upon by Bishop and Henkel (1953).

It seems also necessary to regard the influence of the swelling on the cohesion intercept.

Finally, the *Cohesion method* is also used. We know that it can be applied in the undrained case. We may for instance on the same points as were used for Figs. 10, 12 and 13 use the formula

$$\tan \Phi_c = \frac{\sigma_1 - \sigma_3}{2\sigma_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

where σ_c = the all-around consolidation pressure.

The values of tan Φ_c will then be in the region of 0.325 at $I_p \approx 40$ and 0.35 at $I_p \approx 100$, and the scattering will be on an average about 10 per cent, or nearly the same value as when using the Krey-Tiedemann principles of strength formulas in the version of the present author.

In Fig. 14 a compilation is made of average values of the above-mentioned results of the strength tests. In all cases the tests used are checked to be performed at stresses above the preconsolidation (at natural conditions) stress by control tests, usually 3—4 tests. The values plotted are regularly those from the tests with the highest load.

In the diagram a curve of the values of c/p is also plotted, reduced in a way similar to that used by Olsson. In most laboratory tests the strengthening effect of the secondary consolidation is left unsolved. For that reason, the curves fitted are rather conditional.

It may be asked which of the curves plotted in Fig. 14 should be used. The tan Φ'-curve seems obviously wrong. The tan Φ'_{1c}-curve may be too high, the interpreting method more suited to long-term tests. Of the curves from triaxial results, the minor scattering is on the Φ'_{nc}-curve which is also more conservative than the others, and which may be used when interpreting quick tests. The Φ_d-values for drained tests are also arrived at in a reasonable way.

Of the curves for undrained strength, the tan Φ_{cu}-curve at high values of I_p and the reduced c/p-curve are most conservative. The tan Φ_{cu}-values at low I_p do not seem to be performed on fully undrained samples, and are not to be used.

The choice of the test method should be made with due regard to the specificity of the actual problem. Time influences and manner of consolidation (and possible decrease in effective stresses) seem thus to be most important effects and these will be more carefully investigated later on. A final solution of the problem demands extended physico-chemical considerations, as for instance to thixotropic effects.

Natural conditions

Above, the interpretation of strength results, the influence of time, and particle orientation were discussed in the case of laboratory testings. Such influences can also be observed in natural conditions.[1]

Fig. 15 for instance shows some results of measurements on electrical resistance in the soil, performed vertically and horizontally on samples taken. As might be imagined, the latter resistance is smaller, the plane of most particles being orientated in a horizontal direction. This fact may arise initially at sedimentation or be caused later on by overburden pressures. The same effect can be studied on permeability tests, performed in both directions.

In Sweden, visible deformations can often be observed in the upper regions of slopes. This phenomenon may, however, be rather harmless, the outer parts

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[1] B. Fellenius (1955) has pointed out creep settlements of piles in clay.

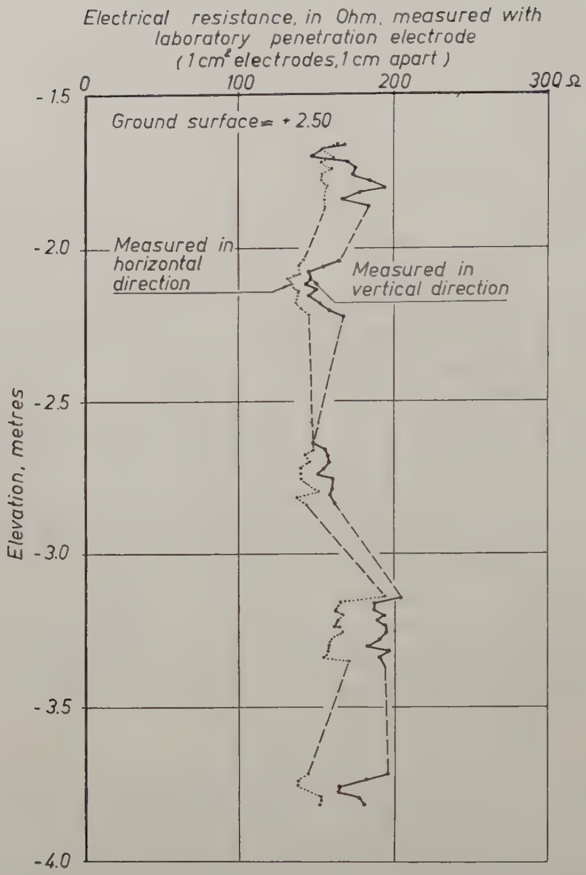

Fig. 15. Electrical resistance in Ohms, measured with laboratory penetration electrodes (1 cm² surfaces. 1 cm. apart), in Skå-Edeby clay.

of the slopes being in the state of slight creeping, but may also depend on a state of stress very near to failure.

If one dares to draw any conclusions from the theories of the above, creep will start at shearing stresses higher than those of final settlements of a level terrain. The plastic deformations will thus be limited to some high-stressed regions.

The velocity of creep may be in a certain relation to the amount of overexertion. Fig. 16 shows a slope, where in a plastic region it is supposed that a slip failure will occur along a surface (or rather a zone), which is kinematically possible, taking into account volume changes that occur. As the sliding body is supported in a highly statically indeterminate way, the distribution of subgrade reactions must be regarded as rather arbitrary.

One often uses a definite shear strength value as a criterion on the resistance against sliding. That must, however, be made with some caution. In

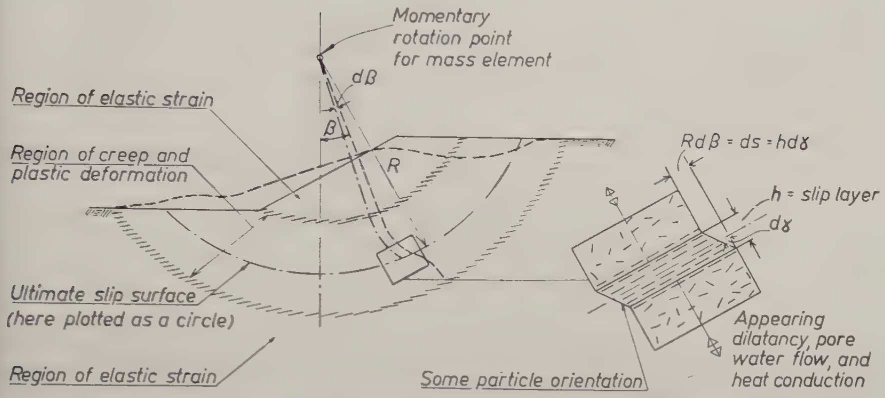
Momentary rotation point for mass element
dβ
Region of elastic strain
β
Region of creep and plastic deformation
R
Rdβ = ds = hdγ
h = slip layer
dγ
Ultimate slip surface (here plotted as a circle)
Region of elastic strain
Some particle orientation
Appearing dilatancy, pore water flow, and heat conduction

Fig. 16. Theoretical behaviour of high-stressed slope and principles of failure. Failure zone *h* in thickness.

this connection, see Peterson, Jaspar, Rivard and Iversen (1960), who state that the stability of embankments on slightly overconsolidated, very plastic clays is overestimated according to both the "total stress" method and the "effective stress" method, and recommend reduction of laboratory test results to avoid the calculated, too high safety factors.

The concept of a certain strength is also rather primitive in reality. As can be seen immediately, sand in bulk, for instance, has no cohesive strength, but it shows resistance to shear, mainly arising from grain contact forces which, during the shear, form works when the grains travel, see Osterman (1959).

For an accurate estimation of the shearing resistance of a slope one should really make an extensive study of the stability of the system from the thermodynamic point of view. Normally, however, one must confine oneself to get an idea of the main amounts of energy mobilized at a real or virtual displacement, arising during an estimated time, and to find out if that event will occur under drainage.

Thus, in the figure one may study the loss of potential energy of the sliding body, when it is turning at an angle of $d\beta$ (or in other cases travelling a certain distance). Strain-work appearing in the body proper can often be ignored.

The study consists also in estimating the work occurring in the slip layer h when it is sheared at an angle of $d\gamma$. The latter energy mainly comes from shearing and outer dilatancy.

At the deformation some energy may be dissipated by thermal effects during the time dt and pore water flow in a direction normal to the slip surface. Of special interest in this connection is any transfer between intergranular stress and pore water pressure arising from inner dilatancy, and changes in frictional resistance emanating from such transfer.

In simple practical cases the calculation must thus be confined to a study of the equilibrium conditions, with regard only to the main situation of drainage in the actual case. In extreme or theoretical cases it seems as if a thermo-dynamical investigation should be worth while. The principles of the mathematical treatment are, however, rather intricate, and will not be discussed here.

Acknowledgements. In making these studies various matters were discussed with Mr. G. Lindskog and Mr. D. Almstedt.

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Aspects on Some Problems of Geotechnical Chemistry

Part II

By

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In part I of this work (Söderblom, 1959), it was shown that dispersing agents of carbonate type may be of great importance for the formation of a local quick clay deposit at »Gärdet» in Stockholm, Sweden.

It was also mentioned that other natural dispersion agents might possibly be certain humates and certain silicates but that it would be difficult to prove their influence. This is due to the fact that it is very difficult to separate a particular silicate existing together with a large surplus of other silicates, e.g. clay minerals, and, in the case of humates, to separate the dispersing humates occurring together with humus gels and other organic material.

Detection and demonstration of natural organic dispersing agents

In spite of the above-mentioned difficulties, it is possible to show the existence of natural clay dispersed by humates. Clay may sometimes be found immediately below a special type of peat deposit from which it is possible to extract a dispersing agent of humate type. The following treatment may be employed:

The peat is treated with a solution of sodium hydroxide and left standing for about two hours. It is then diluted and the insoluble residue filtered off. The filtrate is a dark-brown liquid (hydrosol) of, among other things, sodium humate. The water is then evaporated at 100° C leaving a dark-brown substance which is a rather efficient dispersing agent for certain clays. It is important to note that it is the alkali salt, viz. sodium salt, of the extract which is active. This implies that a clay containing such an extract will be dispersed upon alkalizing with sodium hydroxide. This can be easily illustrated experimentally.

Clay containing humic agents can be found in several places in Sweden, e.g. a clay from Rosenkälla (near Norrtälje) can be mentioned. On treating this clay with different amounts of alkali, the remoulded shear strength varies, as shown in Fig. 1. An addition of about 0.1 g NaOH to 100 g clay will cause a reduction of the H_1-value[1] from 6.2 to 0.34, i.e. an approximately 20-fold decrease. The reduction of H_1 approximately follows the same curve as in the case of dispersion with pyrophosphate and carbonate. According to current

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[1] The H_1-value is a relative strength value determined by fall cone tests on completely remoulded clay. The H_3-value refers to the strength of the undisturbed clay. Cf. part I, p. 729.

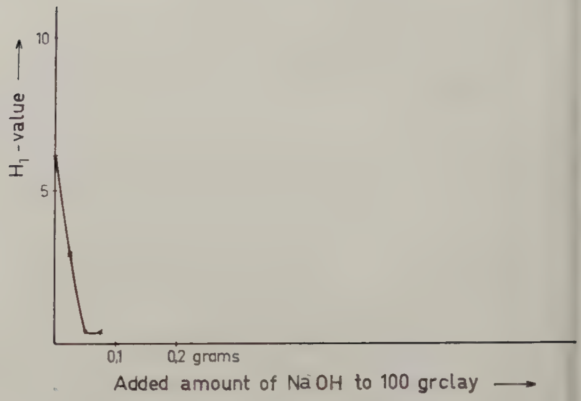

Fig. 1. Influence of alkali on the H_1-value of a humic penetrated clay from Rosenkälla, Sweden (K 6766 sample 8124).

theoretical conceptions of the influence of dispersing agents, this clay should be quick when treated with alkali, which is shown in Table 1. The clay from this site is generally not quick owing to the fact that it is not sufficiently alkaline.

All conditions for quick clay formation of this kind are fulfilled at a site very close to the railway line between Broddby and Rosshyttan. A schematic view of the deposits is shown in Fig. 2. The peat deposit is about 2.9 m thick and, below this, there is a layer of postglacial clay about 0.2 m thick, followed by varved glacial clay. As shown in Fig. 4, the high sensitive clay begins at 3.5 m below ground surface and the sensitivity increases towards the bottom. The quick clay is found in the varved part of the clay deposit.

The laboratory examination performed on a core taken from this site gave the following results. The clay profile is in its full length permeated by humic acid from the peat deposit, which constitutes a dispersing agent for clay in alkaline solution. Thus, the H_1-value and the sensitivity of this clay profile depends on the pH-value. When a sample having a rather high H_1-value is treated with sodium hydroxide, the H_1-value will change as shown in Fig. 3. A slight change in pH may cause a sharp change in H_1 which shows that there can be very small differences in pH between sensitive and insensitive clays.

Table 1. The effect of alkaline solutions on humic-infiltrated clay

(Sample 4155, K 6766, Rosenkälla, Sweden)

Treatment during 48 hours	Cone tests			Notes
	H_3	H_1	H_3/H_1	
None	67.4	11.3	6.0	
Water	25.0	1.37	18.3	
0.1 g NaOH in 0.5 l H_2O	39.5	0.43	91.9	The clay will dissaggregate into dispersed powder. The surface destroyed.
0.2 g NaOH in 0.5 l H_2O	22.8	<0.34	>67.0	The surface disintegrated.
0.3 g NaOH in 0.5 l H_2O	10.2	<0.34	>30.0	The surface disintegrated.
0.5 g NaOH in 0.5 l H_2O	16.5	1.37	12.0	The sample quite destroyed.

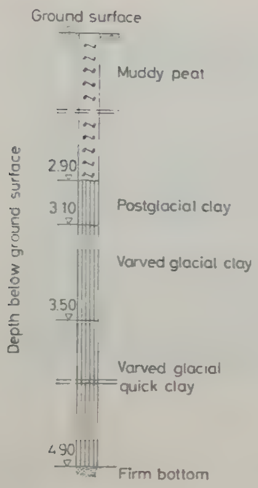

Fig. 2. Schematic view of a clay deposit close to the railway line Broddbo — Rosshyttan, Sweden.

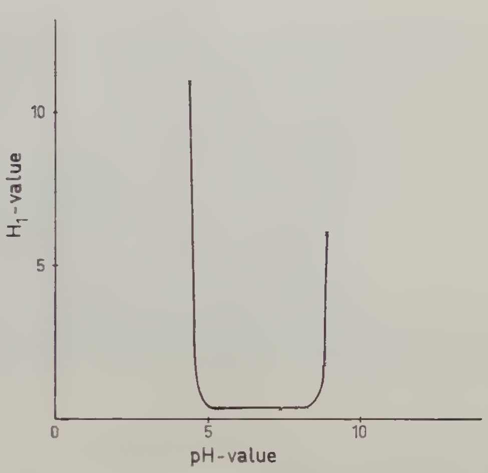

Fig. 3. Influence of alkali on the H_1-value of a clay from Rosshyttan (depth 3.0—3.1 m).

The pH as a function of depth is shown in Fig. 4 and, in agreement with the above discussion, the clay should be most sensitive at the bottom. The sensitivity curve (Fig. 4) shows that this is the case. The agreement between the pH and the sensitivity agrees with the above theory.

A photograph of a clay core is shown in Fig. 5.

A geological examination of the core has been made by T. N. A. Jerbo, Geotechnical Department of the Swedish Railways. The glacial part of the core was proved to be sedimented in fresh water, thus not in saline or brackish water. This clay contains a relatively large amount of organic material. By using a special type of pollen analysis, Mr. Jerbo has succeeded to confirm that

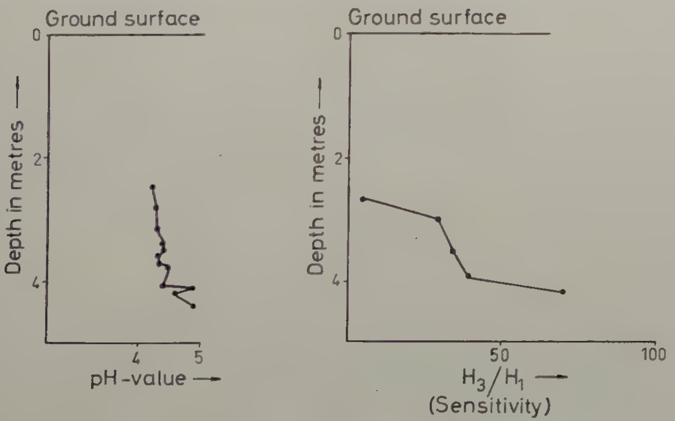

Fig. 4. Comparison between pH-value and sensitivity (H_3/H_1) for a humic penetrated clay from Rosshyttan.

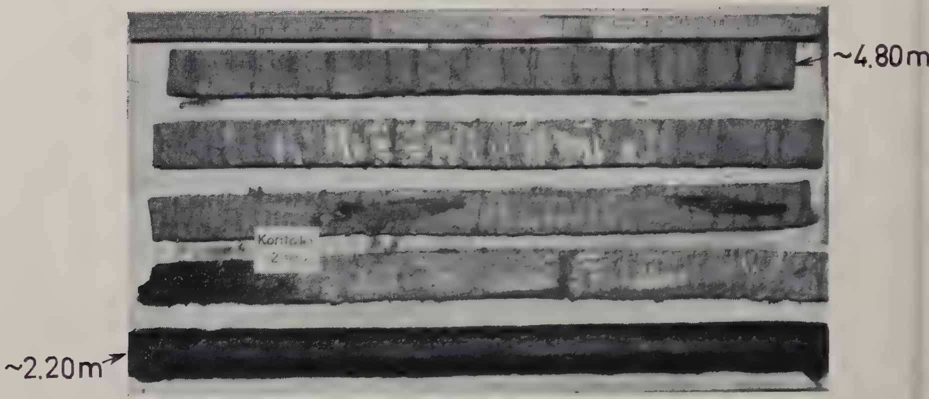

Fig. 5. Photograph of a clay core from Rosshyttan, Sweden.

the organic material in the clay is not derived from organisms sedimented together with the clay material. The clay has undoubtedly received its humus content by infiltration from the peat deposit.

Jerbo has also investigated the occurrence of peat and quick clay at various sites in Sweden and has already found some fifty places where quick clay peptisized by humic substances appears to exist.

Some of the most important places occur on the coast of the Baltic Sea where deposits of fresh water-sedimented quick clay are often situated in the vicinity of layers of organic material. Suspicions have arisen that the organic layer and the resultant clay destruction in its vicinity contributed to the extensive landslide in Kramfors and an examination will therefore be carried out as soon as possible.

Reports on the geological examination of the core taken from Rosshyttan and of the work in Kramfors will be published later by the Swedish Railways

Quick clays of this kind seem to exist even in other countries. Newland and Alley (1955) describe a dark grey clay from Whangamarino, New Zealand, geologically proved to have originally been sedimented in fresh water. This clay underlies a 15-foot layer of peat and was found to be a quick clay.

In Switzerland, fresh water-sedimented quick clays have also been said to exist. Dispersing processes of the kind described above are mentioned by Hager (1948). He maintains that hydroxyl ions coming from the destruction of soil and clay minerals together with organic material will cause a dispersion of the soil material.

Grim (1948) points out that certain chemicals will change the orientation of the water adsorbed on the clay. He has also dealt briefly with the question of the adsorption of organic material on clay.

Emerson (1959) has shown that the organic material in sodium clays causes a dispersion of the clay.

On the other hand, the organic dispersing agents described in the present work do not necessarily consist chemically of sodium humate.

Bloomfield (1956) has made a detailed study of the dispersion of kaolinite by different leaf extracts. He found that the activity of extracts of *Dacrydium franklinii* leaves appeared to be caused by their polysaccharide content and that of *Agathis sautralis* bark by polyphenols. The active components of aspen leaves include a polysaccharide and an acid dispersing agent.

In our case, where the dispersing agents are formed by chemical processes in peat, it seems possible that polysaccharides, oxalates and similar components can also be formed, but a complete chemical study of these processes has not yet been carried out.

In this connection, the dispersing properties of lignin preparations (cf. Lawson 1951) should, in addition, be mentioned.

It is also of interest that tannin preparations (quebracho) are used as dispersing agents for clay in the drilling mud industry (cf. Rogers, 1948, and Alexander, 1946). Tannin can be formed by chemical processes in humus (German Patent, No. 708 466, 1941) and can play some part in the quick clay formation.

Influence of dispersing agents on the strength of a clay

In Sweden it is often necessary to reckon with dispersing reactions in natural clays. It is of interest to study the influence of these substances on the mechanical properties. A literature study shows that this problem has not yet been probed sufficiently. It has often been supposed that processes forming quick clays reduce the shear strength of undisturbed clays only slightly whereas the remoulded clays are strongly attacked — a rather conflicting supposition.

In order to study this question, some experiments were carried out. The first experiments with carbonate dispersing agents (cf. Söderblom, 1959, p. 731) confirmed chiefly the difficulty of influencing the shear strength of undisturbed clay. More systematic experiments with different kinds of dispersing agents showed that some peptizisers do in fact reduce the shear strength of undisturbed clays.

In Tables 2 and 3, a series of experiments illustrating this is shown. Slices

Table 2. The effect of peptiziser-solutions on a clay sample (2996)

Treatment during 24 hours	Cone tests			Notes
	H_3	H_1	H_3/H_1	
None	36.4	3.50	10.4	
1 g Na_2CO_3 0.5 l H_2O	36.9	0.63	58.6	Crack in the sample. No disaggregation
2 g Na_2CO_3 0.5 l H_2O	20.7	0.76	27.2	Some disaggregation
3 g Na_2CO_3 0.5 l H_2O	14.7	0.47	31.3	Some disaggregation
1 g $Na_4P_2O_7$ 0.5 l H_2O	29.0	< 0.34	> 85.3	The clay will disaggregate to dispersed powder. The surface destroyed
2 g $Na_4P_2O_7$ 0.5 l H_2O	22.1	< 0.34	> 65.0	More disaggregated
3 g $Na_4P_2O_7$ 0.5 l H_2O	30.4	< 0.34	> 89.4	The surface disaggregated

Table 3. The effect of acid-alkaline solutions on a humic-infiltrated clay
(Sample 4155, K 6766, Rosenkälla, Sweden

Treatment during 24 hours	Cone tests			Notes
	H_3	H_1	H_3/H_1	
None	101.0	14.3	7.1	—
Distilled water	37.8	8.55	4.4	Cracks in the sample, otherwise unchanged
0.1 g HCl in 0.5 l H_2O....	28.2	6.95	4.1	Unchanged
0.2 g HCl in 0.5 l H_2O....	43.2	10.0	4.3	Cracks in the sample, otherwise unchanged
0.1 g NaOH in 0.5 l H_2O..	57.1	3.23	17.7	Affected on the surface. Dispersed material precipitated
0.2 g NaOH in 0.5 l H_2O..	48.0	1.14	42.1	Strongly attacked, the sample almost disaggregated

of unremoulded clay were placed in solutions of $Na_4P_2O_7$ and Na_2CO_3 at different concentrations and the ions were permitted to diffuse into the sample for 24 hours. As seen in the tables, the influence on the shear strength may increase with increasing concentration of the agent.

The circumstances were found to be the same when peat-impregnated slices of clay were placed in different concentrations of NaOH.

These results indicate a reduction in the shear strength of a natural clay by means of dispersing agents, but the general problems associated with the dispersing process have not yet been definitely solved.

Suitable materials for studies of dispersing processes

Since a natural clay is of heterogeneous composition and is easy to separate into fractions of different particle sizes which react differently to dispersion and since the fractions vary relatively in quantity and activity from one clay to another, a different test material would be more suitable for our principle investigations.

The ideal material would be a synthetic clay having reproducible properties and being available in large amounts, but such a material has hitherto been impossible to find.

Because the clay fraction of the Swedish clays consists principally of illite, it would seem suitable to choose illite as a model material.

A fractionated and completely classified illite clay would be the best material in our case but, because of the difficulties involved in producing such a clay, we have initially chosen another material which is more easily obtainable.

In the present methodological studies, kaolinite was chosen as a rather pure material although unfortunately its properties differ to a certain extent from those of the Swedish natural clays. For example, kaolinite generally has a smaller water-adsorbing power than a Swedish clay. The dispersing effects seem to be the same for kaolinite and natural clay and this fact determined our choise of kaolin for study purposes. However, the various samples of the same material appear to differ from each other, thus making it necessary to test the material carefully before use.

Model studies on kaolin

The dispersing effect depends on the water content of the system. This can be studied by measuring the dispersibility at different water contents. In such an investigation, the best method is to plot the results obtained in so-called consistence-curves for the system kaolin-water.

Table 4. **Consolidation and dispersing of kaolin-silt and natural clay**

Treatment	Cone test			Notes
	H_3	H_1	H_3/H_1	
Kaolin consol. 2 kg/cm^2 4 hrs.	33.2	29.4	1.1	
Silty fine-sand (coarse material, cons. 2 kg cm^2.	295.0 95.0	2.05 2.05	143.9 46.3	Inhomogeneous
50 % kaolin + 50 % coarse material cons. 2 kg/cm^2 4 hrs.	33.2	16.9	2.0	
Kaolin cons. 2 kg/cm^2 4 hrs, treated with 1 g $Na_4P_2O_7$ in 500 ml H_2O.	—	—	—	Liquid
50 % kaolin + 50 % coarse material cons. 2 kg/cm^2 4 hrs treated with 1 g $Na_4P_2O_7$ in 500 ml H_2O.	—	—	—	Liquid
Kaolin cons. 2 kg/cm^2 4 hrs, treated with 0.2 g $Na_4P_2O_7$ in 500 ml H_2O.	—	—	—	Liquid
50 % kaolin + 50 % coarse materials cons. 2 kg/cm^2 4 hrs, treated with 0,2 g $Na_4P_2O_7$ in 500 ml H_2O.	434	0.36	1205	
50 % kaolin + 50 % coarse material cons. 2 kg/cm^2 4 hrs, treated with 1 g Na_2CO_3 in 500 ml H_2O.	526	<0.34	>1547	
50 % kaolin + 50 % coarse material cons. 2 kg/cm^2 4 hrs, treated with 0.2 g Na_2CO_3 in 500 ml H_2O.	386	22.1	17.5	
Glac. clay recons. 2 kg/cm^2 72 hrs. Treated with 1 g $Na_4P_2O_7$ in 500 ml H_2O 24 hrs.	163	4.71	34.6	

EXPERIMENTAL PROCEDURE

200 grams of kaolin and 100 grams of water were carefully mixed and homogenized. The remoulded shear strength (H_1) was determined by a fall cone test. One ml of water was added from a burette, the mixture carefully homogenized and the resulting H_1-value determined. The experiment was continued in this manner until the H_1-value had decreased to a non-measurable quantity (< 0.34). H_1 was then plotted against the amount of added water.

In Fig. 6, the curve for the system 200 grams kaolin/100 grams water is shown with and without the addition of 1 gram Na_2CO_3 to 500 grams of clay as a dispersing agent. The dispersing agent causes the shear strength curve (H_1-value) to drop much more quickly but the curves seem to approach each other asymptotically at high and low water contents.

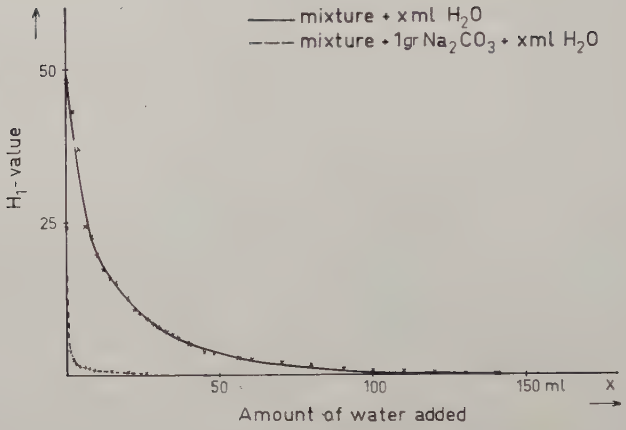

Fig. 6. Influence of water on the H_1-value of a mixture of 200 g dry kaolin and 100 g water.

The same effect was found when using Swedish natural clay. Fig. 7 shows the corresponding curve for Frescati-clay and carbonate. The curve is very similar to the kaolin curve. Possibly, this phenomenon may explain why quick clay upon consolidation loses its sensitivity.

If kaolin is dispersed with $Na_4P_2O_7$ and the mixture partly dried, an elastic material is obtained which can be formed into a ball. When rapidly stressed, this material gives a brittle rupture and the 100 grams cone test gives a penetration of only a few millimetres. The substance obtained is thus rather firm.

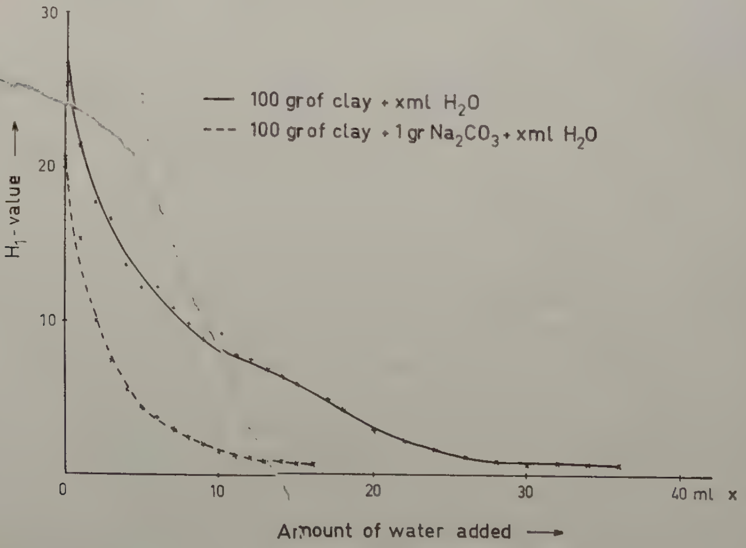

Fig. 7. Influence of water on the H_1-value of a remoulded clay from Frescati, Sweden.

If left under gravitational load for a few seconds, it will disaggregate, giving rise to a shear strength which is too low to be determined by the cone test.

This seems to indicate that the clay has lost its cohesive properties showing dilatancy.

SENSITIVITY EXPERIMENTS

If an unremoulded dispersible clay sample is treated with a solution of a dispersing agent, no essential difference in the mechanical properties is in most cases noticed until the sample is remoulded and broken down. The fact that the unremoulded shear strength may be differently affected is of special interest for reactions of this kind.

The results obtained in these experiments have lead to the following preliminary point of view.

The quick clays examined are built up of a skeleton of uninfluenced coarse material which is non-cohesive, and this is mixed with cohesive material in which the cohesive properties are reduced by the influence of dispersing agents. The clay is thus sensitive to mechanical changes in the non-cohesive skeleton.

Balls made of kaolin and water were placed in various solutions of a number of dispersing agents of different concentrations. In all cases, the balls were disaggregated to a powder.

The experiments were extended to comprise tests on kaolins which had been consolidated before the chemical treatment. A solution of pyrophosphate was allowed to trickle through the sample after concluded consolidation. Also in this case it was impossible to measure a sensitivity because the sample became a liquid.

This seems to point to the difficulties of building up a high sensitivity by dispersing pure clay material.

In the literature it is concluded that a salt-coagulated material is necessary in order to form a metastable sensitive product. However, the pronounced tendency of the glacial clays to become quick upon treating with dispersing agents and, in particular, the natural fresh water sedimented quick clays contradict such a conclusion.

According to the above, sensitivity should be formed if, instead of pure kaolin, we use kaolin mixed with coarser material. For this reason, consolidation experiments were performed on mixtures of kaolin-silt, and dispersing agents were allowed to trickle through the sample exactly as in the use of pure kaolin. By careful dispersion, very high sensitivities were obtained. If the influence is made stronger, the colloidal material will begin to flow and the system will disaggregate similarly to the case of a natural clay, cf. p. 373.

In natural quick clay, it seems possible that organic gels will give rise to an increased viscosity.[1]

The organic material in a clay appears as several different chemical substances — some of which possess dispersing properties. This points to the impossibility of getting a relation between the content of organic dispersing agents in a clay and the carbon content.

As mentioned above, it is only the colloidal fraction of a natural clay which is influenced by a dispersing agent. Preliminary experiments have shown that even the colloidal fraction of a clay contains undispersible constituents.

Dispersibility of different types of clays

Not all types of Swedish natural clays are influenced by dispersing agents and the influence seems to differ for various dispersing agents. Pyrophosphates and oxalates seem to reduce the remoulded shear strength of most Swedish clays but it is very common to find clays that are only slightly affected by carbonates and humates.

Hitherto only qualitative experiments concerning these effects have been made, i.e. we have investigated whether a specially treated clay is dispersible or not. The preliminary tests will be supplemented by quantitative tests.

It is possible by chemical means to transform an undispersible clay into a dispersible form and it seems that the positive ions of the system play a decisive rôle.

The content of exchangeable ions in all the systems investigated was below the critical value specific for the system in question with regard to its mechanical stability. The tests showed essentially that Na^+ Ca^{2+} and Fe^{3+} clays are dispersible. If an undispersible clay is boiled with NaCl, $CaCl_2$ or $FeCl_3$ and the clay is then filtered off and leached, it becomes dispersible. The effect appeared to be greatest in the case of Fe^{3+}.

EXPERIMENTS

The material used was black sulphide clay from Älvängen having the geotechnical constants shown in Table 5. The first step in the examination was to expose the sample to salt leaching. According to Table 5, this treatment did not seem to give a quick clay. In both the natural state and in the leached state, the clay was undispersible by humates and carbonates. When the clay, was boiled with dilute HNO_3, the Fe^{2+} sulphides were dissolved and the iron

Table 5. Influence of salt leaching of the properties of clay from Älvängen, Sweden

Treatment	Cone tests			Resistance, electr. Ω	Notes
	H_3	H_1	H_3/H_1		
None	128	24.3	5.3	34	Black postglacial sulphide clay. Not dispersible.
Dialysis for 3 weeks........	52	12.2	4.3	620	Slightly dispersible.
Original clay treated with 1 g Na_2CO_3 100 g clay ..	—	24.3	—	—	Experiments on remoulded clay
Dialyzed, treated with 1 g Na_2CO_3 100 g clay	—	3.06	—	—	

was oxidized to Fe^{3+}, this treatment thus corresponding to a boiling of undispersible clay with FeCl$_3$, and according to the foregoing the clay became dispersible after leaching. The same effect was obtained when the clay was exposed to water dialysis of a long duration, the iron becoming oxidized to Fe^{3+} and the colour of the clay changing from black to grey. Natural oxidation processes seem however to change this Göta River clay to an easily dispersible material.

Field examinations in the Göta River Valley

The results of the examination of clay from Älvängen showed that salt leaching alone is not sufficient for making the clay from the Göta River Valley highly sensitive. On the other hand, it is possible to do this by a suitable chemical treatment and subsequent exposure of the clay to a dispersing process. This indicates the possibility of the existence of natural dispersing processes in the valley and it seems to be of great importance to ascertain whether or not this is the case. This has revealed quite new aspects concerning the question of clay destroying processes.

The rather rich occurrence of brown mud and peat deposits in this valley and on the ridges points to the possibility of humic dispersing processes similar to those at Rosshyttan.

At certain levels, the clay also has permeable layers of silt and sand. In many cases, brown-coloured humic water flows through these layers. This water is relatively acid and possesses a certain hydrostatic pressure.

A clay having such a layer is shown in Fig. 8. Humates penetrate into the clay from this layer. The permeation takes place under acid conditions according to Forslind (for instance, 1948), and may give a stabilization of the water lattice and thus no humates penetrate the individual clay crystals and the clay is not dispersed. At a greater distance from the layer, the clay is alkaline and thus sensitive to the influence of the humates.

The insensitive clay in the vicinity of the layer would on the other hand be easily dispersed by alkali, a fact which is employed in the following.

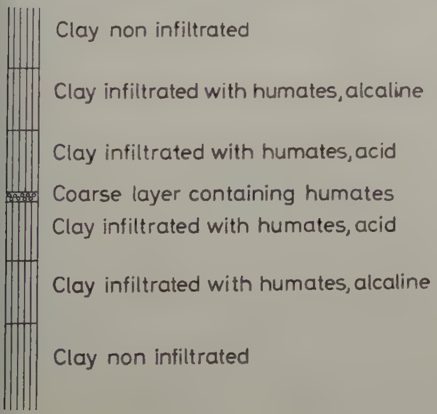
Clay non infiltrated
Clay infiltrated with humates, alcaline
Clay infiltrated with humates, acid
Coarse layer containing humates
Clay infiltrated with humates, acid
Clay infiltrated with humates, alcaline
Clay non infiltrated

Fig. 8. Penetration of humates in a clay containing a permeable layer.

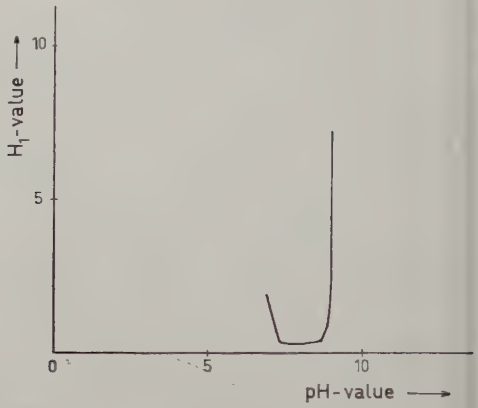

Fig. 9. Influence of alkali on the H_1-value of a clay from Göta, Sweden (depth 2.80 m).

Fig. 9 contains a curve illustrating the influence of alkali on a clay from Göta taken at a level where we have to expect humic infiltration at a sensitivity minimum. The H_1-value is lowered by alkali and the curve for the H_1 at different pH is similar to that obtained for the Rosshyttan clay. This indicates clearly the occurrence of processes of the same kind in both cases. Other similar experiments have shown that dispersing processes of this kind are probably relatively common in the Göta River Valley.

Examination of the dispersibility of natural clays have hitherto not been carried out systematically, due to the short time which has elapsed since the detection of these processes in Nature. We have therefore first of all attempted to find a suitable field method.

The method adopted is as follows:

The sensitivity and shear strength is measured by vane borings. Salt sounding curves are taken parallelly. If the clay is salt, this seems to be sufficient for the clay to be assumed insensitive. Hitherto we have not found salt quick clays in Sweden. According to Newland and Alley (1955), such clays exist at least in New Zealand.

If the clay is not saline and not quick, it is tested for dispersibility. For simplicity, remoulded samples are taken with a side-intake sampler from every 1/2 metre. The H_1-value is determined by a cone test and, thereafter, the sample is made alkaline with sodium hydroxide until the H_1-value has reached a minimum. The quotient of the H_1-value in the natural state and the value in the alkaline state is a measure of the dispersibility and the humic permeation of the clay. It is also a rough measure of the sensitivity which, in this special case, can arise as a consequence of increased alkalinity.

If the clay is not dispersible by sodium hydroxide and is not quick but there is nevertheless a peat deposit, an examination is carried out to discover whether humate isolated from the deposit will disperse the clay or not. If the clay is dispersed by humate, it is possible that the dispersing agent has not reached the clay. If not, it is considered to be an undispersible type and the possible chemical reactions which may give rise to dispersibility are then studied.

Table 6. Influence of alkali of clay samples from a profile from Intagan, Sweden

Depth below ground surface in metres	H_1-value before treatment	H_1-value after treatment	Dispersibility	pH-value	Notes
3	28.4	25.0	1.1	6.8	
3.5	16.9	12.2	1.4	7.2	
4.5	7.1	6.9	1.0	7.5	
5	5.5	3.8	1.4	7.8	
6	1.5	1.3	1.2	7.9	Disp. with peat extr. 4.5
9	5.8	4.4	1.3	7.9	
13	8.1	5.8	1.4	7.9	

By examinations of this kind, we have found satisfactory support for our theories in a profile taken from a site near Intagan, Göta River Valley. The strength reduction for sodium hydroxide is very low near the river. Here isolated humates are dispersible (Table 6). The clay is rather alkaline in the whole profile and, at some levels, it is highly sensitive. This shows that the insensitive parts of the profile in this case probably lack sufficient amounts of dispersing agents.

At a greater distance from the river (about 500 m), the clay is more dispersible by alkali (Fig. 10). This indicates a greater permeation than that near the river. The clay is most sensitive at the bottom where it is also most alkaline.

At a still greater distance from the river, the clay is very insensitive but shows a great dispersibility when treated with sodium hydroxide (Fig. 11). This indicates a high permeation. At depths of 3.5 and 5.5 m, there are distinct layers of sand which are brown-coloured due to the flowing water. At these levels (especially at 5.5 m), the pH value shows a minimum and the H_1-value reaches a maximum. According to the theory given here, the H_1-value should be low at levels where the pH is high and the figure also shows that this is in fact the case. In the vicinity of the coarser layers, the clay should show the highest dispersibility and this too appears to be correct. If this clay is alkalized, it will show the highest sensitivity at the levels where it is most dispersible and, if the permeation is the same at a place where the clay is

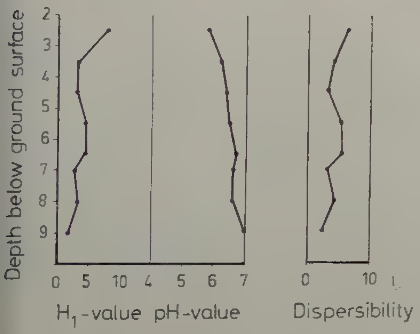

Fig. 10. Influence of alkali on a clay profile from Intagan, Sweden. Depths in metres.

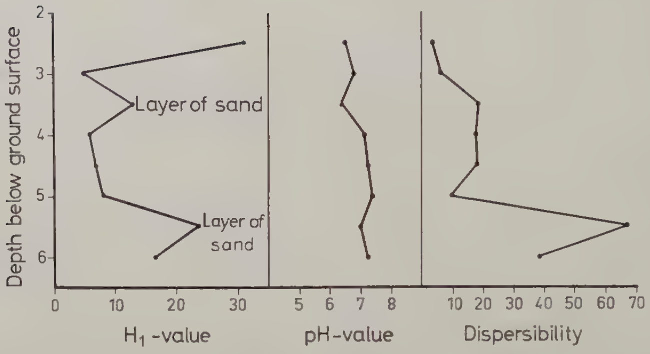

Fig. 11. Influence of alkali on a clay profile from Intagan, Sweden. Depths in metres.

more alkalized, the sensitivity curve should correspond to the dispersibility curve. Some sensitivity curves from this section indicate such a relation (Fig. 12).

The results obtained show that, in this section, we have to reckon with a permeation of humic material coming from the vicinity of the ridge and following the coarser layer in the clay. An examination showed that, on the top of the ridge, there are marshy grounds containing peat with dispersing properties. Maps indicate that peat deposits of this kind are common in the Göta River Valley and consequently we must often reckon with processes of this kind. The lateral destruction of the clay will also explain why quick clays often occur in a certain region situated between the river and the ridge.

Natural carbonates and other agents may play an important part but, owing to the obvious character of the humate processes, the possible carbonate processes have not yet been examined.

It is of interest to investigate whether a correlation exists between large landslides and peat deposits. Preliminary examinations have been made in Göta and Surte. In Göta, there is a large deposit containing a strong dispersing agent and this deposit has two outflows where permeation may have occurred and which are situated behind a recent large slide. In Surte, too, some peat deposits can be found behind the landslide there.

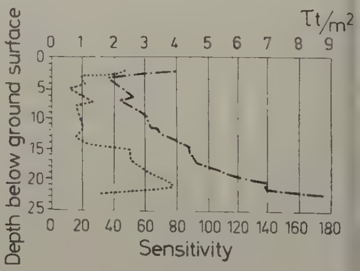

Fig. 12. Shear strength, to the right, and sensitivity curves of a clay profile from Intagan, Sweden. Depths in metres.

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Skredet vid Kyrkviken februari 1959

En preliminär rapport

Av

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Summary: The landslide at Kramfors on the Kyrkviken

From the 1st and to the 4th of February, 1959 a series of slides occurred at the Kyrkviken in the Kramfors area. The last slide cut the Swedich State Railways track connecting Härnösand and Sollefteå (i.e. the East Coast Line = OKB). The slide area has a length of a good 600 metres of which about 200 metres are visible above water level. The deposits in the slide area have in the main a similar character to those in the vicinity of the Kyrkviken.

They have generally the following stratification.

Postglacial black or greengray silty clay with sulphides	Varying depth	Recent
(Gyttje-banded clay)	About 0.5 m	»
Postglacial black silty clay with sulphides	Varying depth	»
Varved silt (with thin clay varves)	≦ 2.5 m	Pleistocene
Glacial till		»
Bedrock		Archaean

On the 5th of February the geotechnical investigations started. Their aims were firstly to make clear how to reestablish the railway; secondly to find out if there were other parts of the track that might be unstable; thirdly to try to find out why and how the slide occurred.

From an economic point of view it was soon clear that the track had to be moved westwards where the ground was stable with only a thin layer of silty clay on the till. Furthermore two places were found, one south (km 458 + 500) and the other north of the slide (km 459 + 000 — 500), where the factor of safety was low. The first place was reinforced with piles (fig 8). On the second place an electric slide-warning system was projected (fig 10).

The slide sediments on the bottom of the Kyrkviken were mapped by measuring their electrical resistances. It was thus found that the slide-masses had passed along the bottom for about 700 m.

Laboratory tests on samples taken every 10—20 cm are shown on fig 7. As can be seen the sediments are loose and partly quick.

The causes of the slide are mainly theree, rubbish which the cleaning department of the town of Kramfors has dumped in the slide area (some days before the slide mainly wet snow); delta sedimentation from a brook; and the land-elevation.

The investigations shows that there have been movements in the slide area during the last years (fig 10). The land-slide probably began with movements in the bottom sediments of the Kyrkviken, then the slide itself began with a section at the shore. Afterwards the soil has moved in sections and the envelope of these seems to be a very quick and loose layer.

The Geotechnical department of the Swedish State Railways plans to give out a more detailed report in its bulletin.

Under tiden den 1—4 februari 1959 skedde en serie skred, varav det sista avskar ostkustbanan (OKB) vid Kyrkvikens västra strand ca 1 km söder om Kramfors.

Som av generalstabsbladet 75 Härnösand N.V. framgår är Kyrkviken en vik till Ångermanälven. Vikens bottentopografi på skredplatsen karaktäriseras av en långsamt sluttande botten ut till den centrala delen, där före skredet bottendjupet var ca 35 m.

I viken är miljön stagnant, enär utloppet i Ångermanälven blott är ca 3 m djupt. Tillflödena till viken är små. Av betydelse är blott ett i vikens nordvästra och ett i dess södra del.

Båda har utbildat delta. Kyrkvikens stränder består till övervägande del av sediment av postglacial typ. Morän och fast berg är sparsamt förekommande. Moränen är i ytan svallad och normalblockig. Hällarna i vikens södra del är utbildade som rundhällar under det att de i norr och väst genomkorsas av förkastningar och omvandlingszoner. Bergarterna kring Kyrkviken tillhör Härnöseriens graniter och pegmatiter.

Moränen, som delvis är nedpressad i rösberget, utgöres i sin undre del av en stålgrå, mjälig blockfattig hårt pressad bottenmorän med låg vattenhalt, men flytbenägen i omrört tillstånd vid vattentillskott. Ytmoränen har hög mohalt och är rel. blockfattig. Mängden ytblock är däremot vanligen stor. De glaciala sedimenten består av varviga mjälor med tunna lerskikt med en mäktighet ej överstigande 2.5 m. I sin äldre del består de postglaciala sedimenten av mjäliga sulfidhaltiga leror (varviga). Ovanpå dessa följer en gyttjebandad lera med en rel. konstant mäktighet (ca 50 cm) överlagrad av sulfidleror.

Under åren 1932—33 utfördes en genomgående geoteknisk översiktslinjeundersökning inom det av skredet berörda stationshållet Frånö—Kramfors på ostkustbanan. I samband med elektrifieringsarbetena kompletterades åren 1956—57 utförda undersökningar med vissa provtagningar, och 1957 utlades på skredplatsen en mindre tryckbank 75 cm tjock och med krönkant 20 m från spårmitt för att säkerställa spårets stabilitet.

Omedelbart söder om skredplatsen ligger banan i en liten bergskärning. Utanför denna åt söder har sedan lång tid tillbaka Kramfors stad tömt sopor ut i Kyrkviken. Under år 1958 påbörjades även tippning utanför ovannämnda tryckbank i riktning norrut. I slutet av januari 1959 tippades efter rikliga snöfall blötsnö och sköts med traktor ut mot tippkanten. Härvid skedde mindre rörelser i tippen.

Det första observerade skredet (skred fig. 1) inträffade natten mellan den 1 och 2 februari och gick fram till tryckbankens fot. På morgonen den 2 februari upptäcktes även att isen var uppbruten på ca 400 m längd efter stranden norr om skredet. Detta undervattensskred måste alltså ha skett samtidigt som skred 1, eller möjligen något tidigare eller senare. I en underhandsrapport utgiven den 7. 2. 59 (Fellenius 1959) antogs att isen uppbrutits av en vågrörelse efter skredet. Undersökningarna visade dock snart att det verkligen rör sig om ett undervattensskred.

I samband med att skred 1 upptäcktes infördes skärpt bevakning och ned-

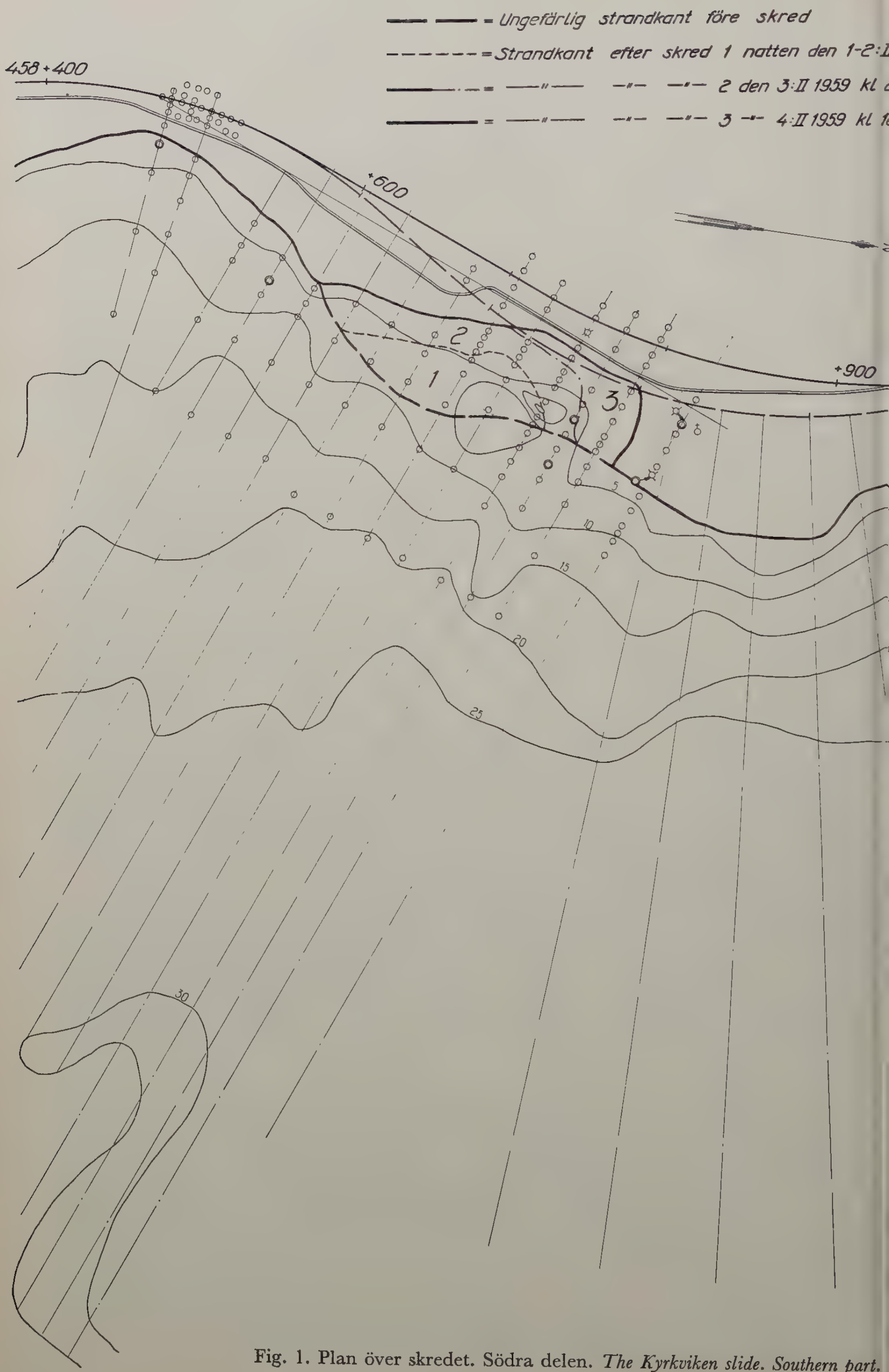

= Ungefärlig strandkant före skred
= Strandkant efter skred 1 natten den 1-2:
= —"— —"— —"— 2 den 3:II 1959 kl
= —"— —"— —"— 3 —"— 4:II 1959 kl
458+400
+600
+900
1
2
3
5
10
15
20
25
30

Fig. 1. Plan över skredet. Södra delen. *The Kyrkviken slide. Southern part.*

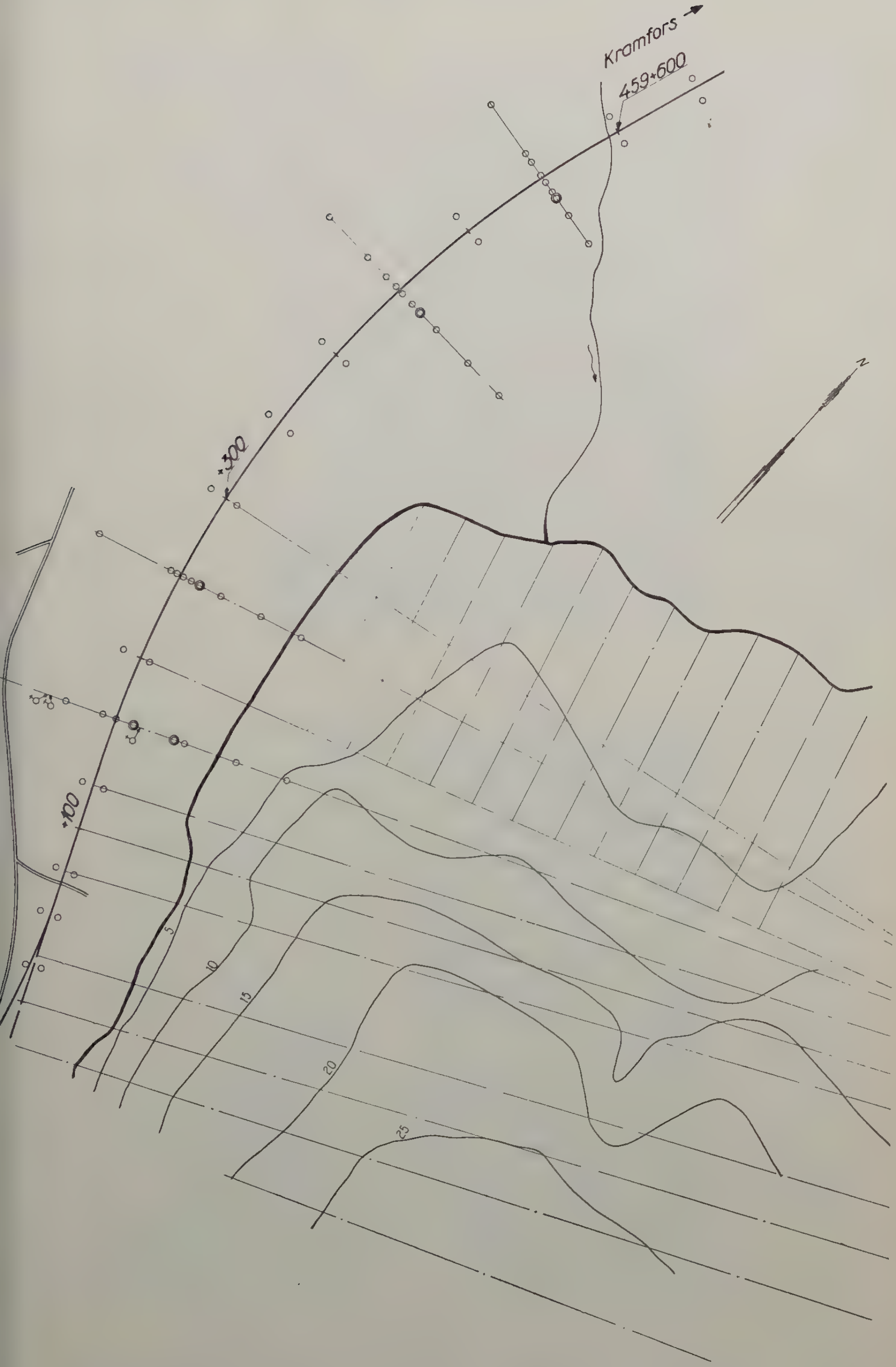


Fig. 2. Plan över skredet. Norra delen. *The Kyrkviken slide. Northern part.*

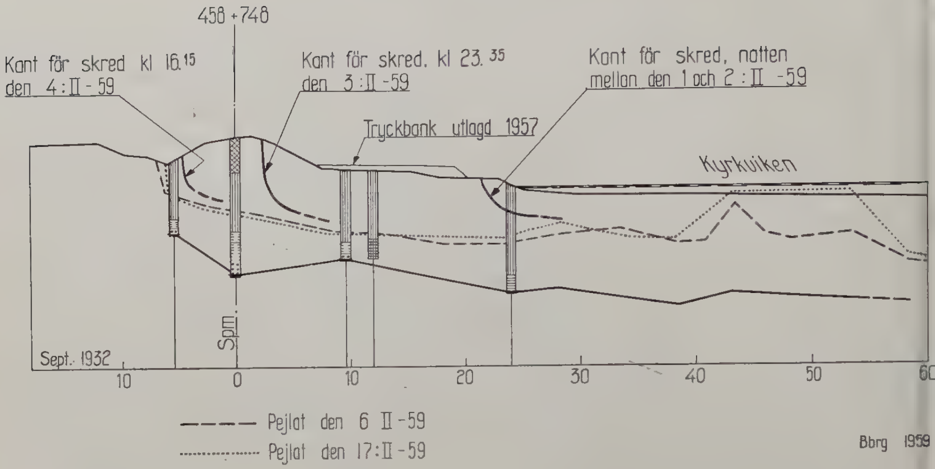

458 + 748
Kant för skred kl 16.15 den 4:II-59
Kant för skred. kl 23.35 den 3:II-59
Kant för skred, natten mellan den 1 och 2:II-59
Tryckbank utlagd 1957
Kyrkviken
Spm.
Sept. 1932
10
0
10
20
30
40
50
6
Pejlat den 6 II-59
Pejlat den 17:II-59
Bbrg 1959

Fig. 3. Tvärsektion genom skredet. *Cross-section of the slide.*

sattes hastigheten på banan. Skred 2 inträffade natten den 3 februari kl. 23.35 och bevittnades av Grels Berglund. Detta skred gick fram till spårets bankfot och tog med sig tryckbanken samt el-stolparna för linjedriften. Skred 3, som närmare beskrivits i ovannämnd underhandsrapport, bevittnades av bl. a. Bror Fellenius och inträffade den 4 februari kl. 16.15. Härvid avbröts järnvägsbanken på en ca 80 m lång sträcka. Därefter har endast mindre eftersläntskred skett, så att bankavbrottet ökats till drygt 100 m. Den totalt utskridna sträckan rör sig om drygt 600 m. På fig. 3 visas en tvärsektion (km 458 + 748), tagen i mitten av det ovan mark synliga skredet. Här syns bankens profil och Kyrkvikens bottenkontur före skredet samt den år 1957 utlagda tryckbanken. Vidare har inlagts de olika skredens ungefärliga omfattning samt resultatet av två senare utförda pejlingar. Fig. 4 ger en bild av skredet.

Redan den 5 februari på morgonen ankom geotekniska avdelningens laboratorievagn fullt utrustad till skredplatsen. I första hand upplades mätningsarbetet och utfördes den snabbkartering, som låg till grund för de skisser, som bifogades tidigare nämnd rapport den 7. 2. 59, och igångsattes de borrningar, som var erforderliga för att kunna besluta om hur banan skulle återuppbyggas. Med anledning härav utfördes i första hand en sondering från ca km 458 + 700 — 800 närmast utanför skredkanten och västerut mot fastmarken. Undersökningen kompletterades med vingborr och kolvborrprovtagning samt portryckmätning. Det kunde snart konstateras att det icke, med hänsyn till kostnaderna, var försvarligt att återställa linjen i befintligt läge, då mycket stora massor måste bortschaktas för att kunna föra ned banken till fast botten. Att genom successiv utfyllning och överbelastning genom skred så småningom pressa ned banken till fast botten ansågs icke heller lämpligt på grund av stor massåtgång, lång byggnadstid och risk för vattenrättsliga konflikter. Det beslöts i stället att genom kurvförbättringar draga in linjen västerut så långt från

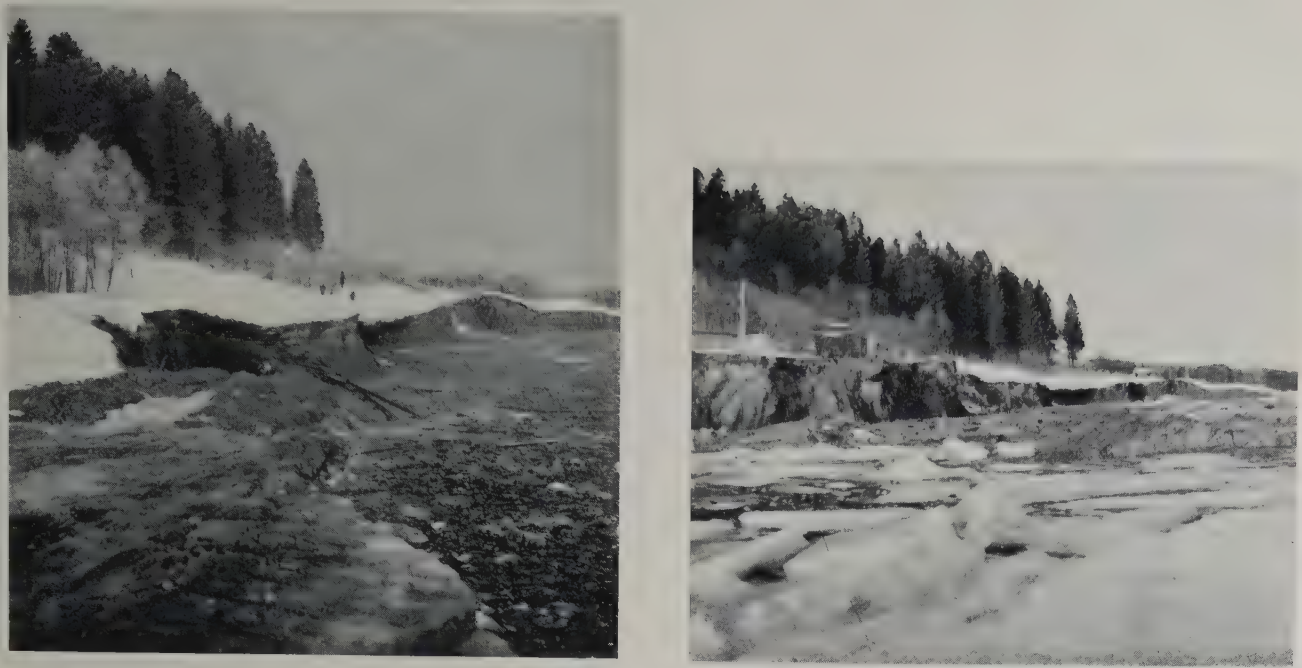


Fig. 4. Vy över huvuddelen av den över vattenytan synliga delen av skredet tagen norrut.
Grand photo showing the greater part of the slide above the waterlevel. North is in the camera direction.

skredet, att den kunde läggas antingen på fastmark eller genom urgrävning nedföras till fast botten (fig. 1 och 2). Så snart linjesträckningen fastställts, kunde undersökningarna utbredas över hela skredområdet och närliggande linjesträckor. Härvid befanns att för ytterligare två områden stabilitetsförhållandena var sådana, att närmare undersökningar erfordrades, nämligen vid km 458 + 500 och sträckan 459 + 100 — 300. Borrningsarbetet inom själva skredområdet var så riskabelt, på grund av risken för smärre efterskred, att personalen i viss utsträckning arbetade under bevakning och med livlinor.

Utanför norra änden av skredet inmättes en jämförelsetvärsektion (458 + 815). Under arbetenas gång skred emellertid här en mindre skålla, varför slutlig jämförelsesektion (458 + 827,5) inom oskridet område måste utflyttas. Sedan arbetena fortskridit så långt, att vad som kunde säkrats av uppgifter inom och i skredet angränsande områden, igångsattes noggranna pejlingar av vikens botten (i en del sektioner över 700 m långa) och ett omfattande arbete påbörjades av avdelningens geolog fil. lic A. Jerbo, för att om möjligt kunna spåra skredmassorna, d. v. s. i bottensedimenten kunna avgöra, vilka, som ligger i primärt läge och vilka, som är sekundärt omlagrade.

Dessa arbeten har närmare beskrivits av Jerbo i ett föredrag under det 3:e nordiska geoteknikermötet i Köpenhamn i sept. 1959 och kommer efter ytterligare bearbetning och komplettering att beskrivas i en slutrapport om skredet. Jag vill bara därför taga upp till behandling huvudprinciperna för dessa mätningar inspirerade av den Söderblomska saltsonden (Söderblom 1957 och 1958). Dock var förutsättningarna för motståndsmätningar av detta slag icke goda, då de förhandenvarande sedimenten i hela sin postglaciala del är rel. likartade med avseende på kornfördelning, gyttjehalt och klorhalt. pH varierar utan något skenbart samband med vattenhalten. Man visste alltså, att om någon ändring av de kemiska komponenterna inom rimliga gränser skedde, så erhölls ingen entydig förändring av ledningsförmågan. Ändras däremot de fysikaliska förutsättningarna t. ex. konsolideringsgraden ändras ledningsförmågan markant. Det är detta, som är avgörande för möjligheten att spåra skredmassorna. Bef. el.sonder lämpade sig icke för dessa arbeten, varför avdelningen i samråd med styrelsens elektrotekniska byrå konstruerade en ny sond för resistansmätning. Instrumenteringen vållade även stora problem och efter ingående försök beslöts att arbeta med växelström i sondkretsen och likström i mätkretsen. Ett instrument med 500 volts 93 periodig fyrkantström ordnades.

Lokalisationen av skredmassorna gick bättre än man trots allt vågat hoppas. Om det ev. var fråga om utskridna massor, erhölls mätvärden, som kastade, som om det varit varvsediment som mätts (se fig. 5 och 6). Att så icke var fallet kontrollerades med jämna mellanrum med hjälp av ett 80 cm profillod av Kullenbergtyp. Det visade sig att man på kort tid kunde lokalisera skredmassorna och konstatera deras mäktighet. Således befanns att skredmassorna flutit längs botten ca 700 m och där lagt sig relativt jämnt över denna och höjt den från 35 till 32 m. u. h. i en tidigare känd punkt. Mäktigheten av skredmassorna var 1—2 m i vikens centrala del och utbredde sig tämligen horison-

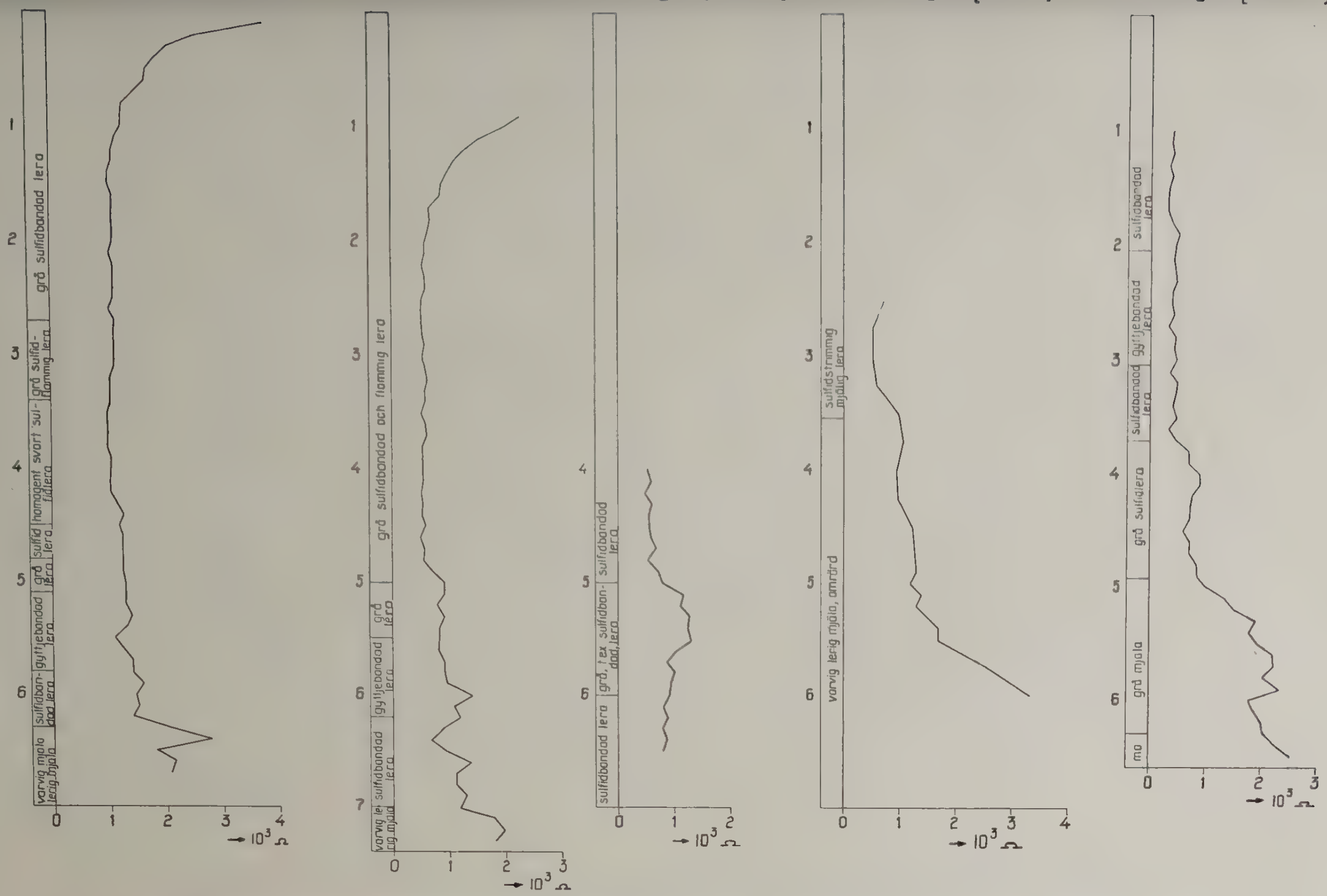


Fig. 5. Några typiska motståndskurvor för Kyrkvikens sediment. *Some typical resistance curves for Kyrkviken sediments.*

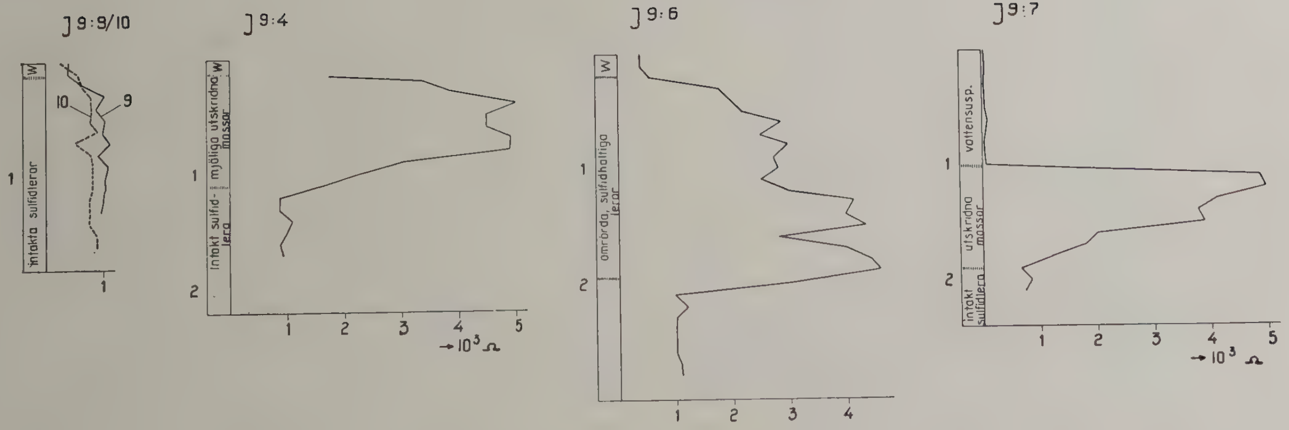


Fig. 6. Motståndskurvor för utskridna massor.
Resistance curves for slide-masses on the sea-floor.

tellt mot SW.W. och NW. Vid senare pejlingar (juni 1959) kunde inga ändringar spåras.

Förutom en omfattande sondering på platsen för bankskredet utfördes även speciella geotekniska undersökningar i tre sektioner (fig. 1). Sålunda utfördes i sektion 458 + 755,7 vingborrning och provtagning med kolvborr, för att utröna om blivande bankropp måste nedföras till moränen eller kunde grundläggas på någon av de lösa sedimenten. I sektion 458 + 772 togs kolvborrprov i skredet för att analysera de under skredbotten kvarvarande sedimenten och i sektion 458 + 827,5 togs en jämförelsesektion inom oskridet område med ving- och kolvborrprov samt portryckmätning. Som tidigare nämnts gjordes här först ett försök i sektion 458 + 815, men ett mindre efterskred tangerade denna sektion och omöjliggjorde vidare arbete. Enär en okulärbesiktning av skredytorna mellan skred 2 och 3 och efter skred 3 icke visat några som helst tecken till porövertryck, var inget sådant att förvänta och påträffades icke heller. Däremot visade både provhålen i den ovan vattenytan oskridna sektionen och i den skridna sektionen synnerligen kvicka leror på samma ställe i lagerföljden. Det var ett skikt sulfidbandad lera på den närmast glacialleran liggande från organiska substanser fria mjälan, som hade H_3/H_1-värden > 100. I övrigt stämde hållfasthetsvärden erhållna med ving- och kolvborr relativt väl överens. Enahanda kvicka sulfidbandade leror påträffades på varvig mjälig lera i sektion 458 + 475. Denna tvärsektion kompletterades dessutom med en omsorgsfull sondering. Undersökningarna visade, att banken icke heller här hade tillfredsställande stabilitetsförhållanden. I sektion 459 + 164 (fig. 2) utfördes även omfattande arbeten. Sedan det konstaterats, att skred skett utanför stranden även i denna sektion, befarades nämligen att genom efterskred banan kunde komma i farozonen. Portryckmätningar gav besked om höga övertryck. Så t. ex. var trycket på samtliga provnivåer omedelbart öster järnvägsbanken ca 2,0 m högre än vikens vattenyta. Även här erhölls en zon med kvicka sediment i samma läge som de föregående, men dessutom påträffades djupare ned kvicka varviga mjäliga leror. I anslutning till denna sektion upptogs även jordprover i sektion 459 + 166 H 70. Dessa analyserades på var 20:e cm från de recenta sedimenten och ned i den på glacialleran liggande postglaciala mjälan (fig. 7). Förutom rent geotekniska egenskaper, har dessutom en serie fysikaliska provningar och kemiska prov utförts i samband med pågående forskningsarbete rörande kvickleror i samarbete med Statens Geotekniska Institut. Resultatet av dessa mätningar är under bearbetning varför de endast skisserats på fig. 7. Vidare har ytterligare arbeten planerats att utföras på skredplatsen i juni i år. Även den på fig. 5 visade motståndsmätningen (core J 5) är utförd i denna sektion (H 68).

På platsen mellan provtagningshålen H 12 och H 35 företog Geotekniska föreningens kolvborrkommitté en jämförande provtagning för att undersöka olika kolvtypers inverkan på ödometerprovningar med hänsyn till kolvdiametern, samt inverkan av trimning på proverna.

Med hänsyn till de resultat, som erhållits på de olika undersökningsplatserna, utfördes följande arbeten för den nya linjens stabilisering. Omkring km

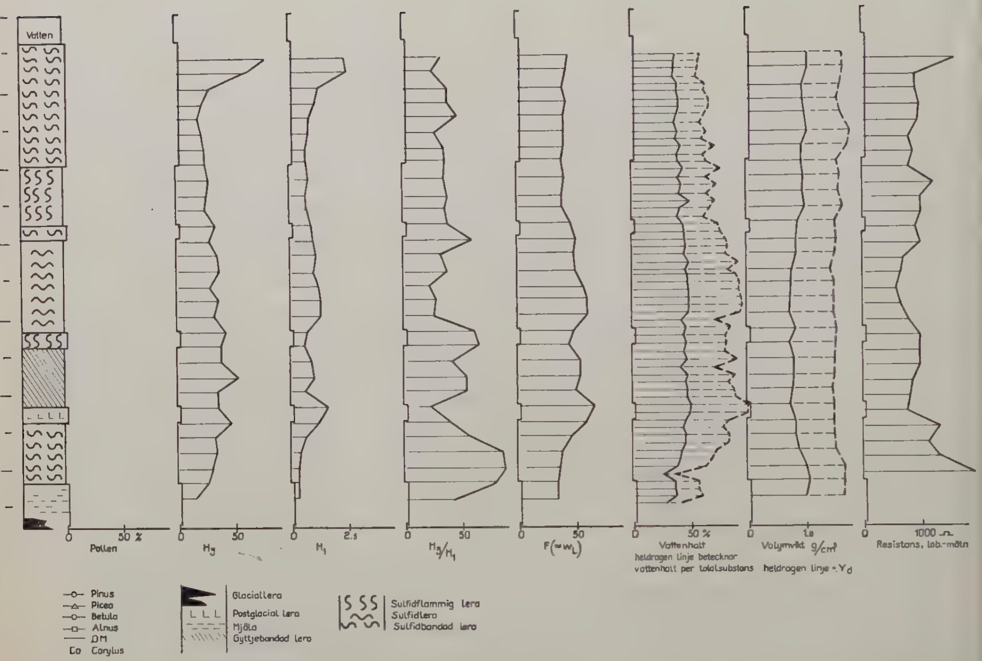
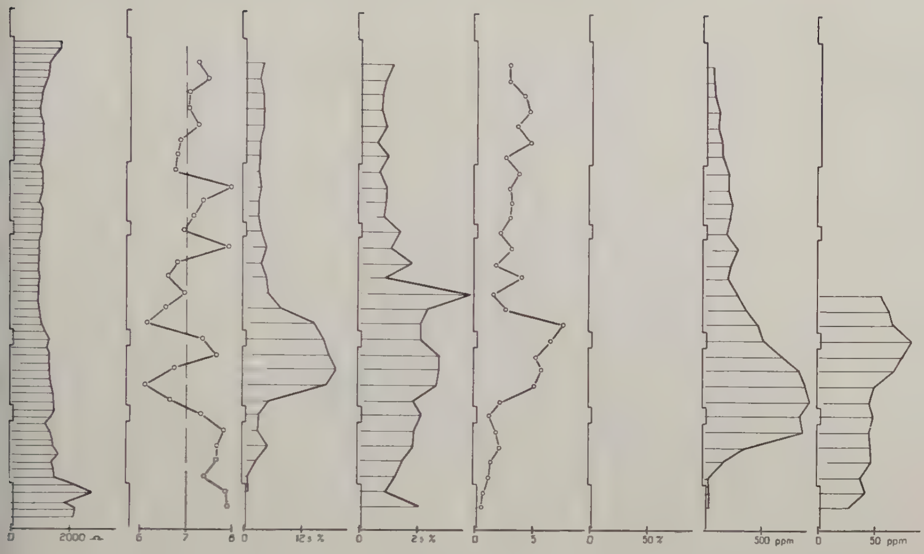


Fig. 7. Diagram, som visar laboratoriedata på var 20 cm för material taget
Laboratory tests on core J5 (km 459 + 116; H 70) with samples taken

548 + 500 utfördes en fyrradig bankpålning (fig. 8). På pålskallarna lades grov blockfyllning och ovanpå denna makadamballast, sedan fyllningens överyta tätats. Ovanför skredområdet företogs urgrävning till fast botten, eller där denna låg högre än frostfritt djup till detta. Det visade sig synnerligen besvärligt, att få skärningsslänterna att stå. Med hänsyn till snöfall och omväxlande blida och kalla perioder blev det nödvändigt att kontinuerligt skydda slänterna. Härvid valdes att bekläda dem med makadam av närmast klass II-typ, enär dylik fanns tillgänglig i närheten. Fick slänterna stå oskyddade, flöt de ut i schakten på grund av materialets mycket höga flytbenägenhet. Ett djupdräneringssystem lades även under släntfotens dagvattendike. Inom sträckan km 459 + 000 — 500 har däremot inga förstärkningar utförts. Om efterskred här utlöses, anses de icke så snabbt hinna »äta sig in» till banvallen, att man icke kan bli varnad i tid, om något automatiskt varningssystem anordnas. Med hänsyn härtill finns planerat ett elektriskt varningssystem, som består av en klen kabel dragen i princip enligt fig. 9 mellan spåren och stranden. Sker skred inom den av kabeln täckta zonen, slits denna av och en signal tänds, som stoppar trafiken. Installation kommer att ske inom den närmaste tiden.

Ehuru arbeten alltjämt pågår, och ännu icke alla pusselbitar finns tillgängliga, är det dock kanske på sin plats att till sist nämna något om skredorsakerna och hur skredet tillgått.

Det är ingen tvekan om, att landhöjningen är en bidragande orsak. Men



i sektion km 459 + 166 H 70. Diagrammen är ännu icke kompletta.
every 10—20 cm. The incomplete diagram shows preliminary results.

vore denna den avgörande faktorn frågar man sig vad som utlöste skredet. Härvid har följande faktorer studerats. 1. Seismiska fenomen. 2. Sprängningsarbeten. 3. Makadamupplag. 4. Deltabildning. 5. Soptippen. Faktor 1 kunde snabbt strykas på listan, enär några lokala skalv icke inregistrerats och den seismiska aktiviteten överhuvudtaget var ringa vid tiden för skredet. Ett mindre skalv hade dock registrerats utanför norska kusten kl. 24.30 den 30. 1. 59. Även faktor 2 visade sig ovidkommande, enär vid kontroll det visade sig att sprängningsarbetena i den stora bergskärningen för riksvägen väster om skredplatsen påbörjades först den 4. 2. 59. Faktor nr 3 är icke helt oväsentlig. Ca 75—95 m väster om spåret i sektion km 459 + 164 ligger norra delen av ett

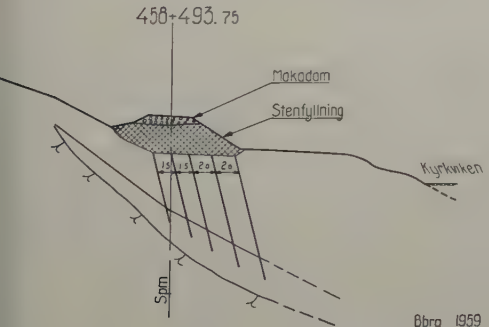


Fig. 8. Principskiss över förstärkning medelst bankpålning.
Sketch of reinforcement with piles.

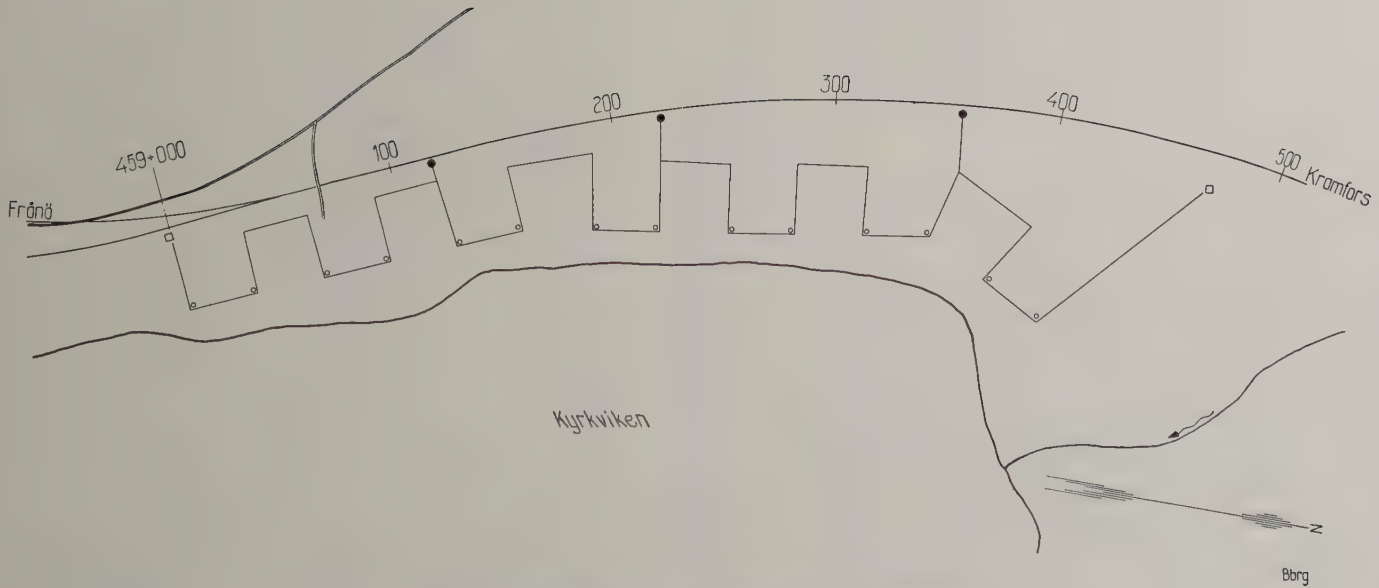


Fig. 9. Principskiss över elektriskt skredvarningssystem.
Sketch of the electrical slide-warning system.

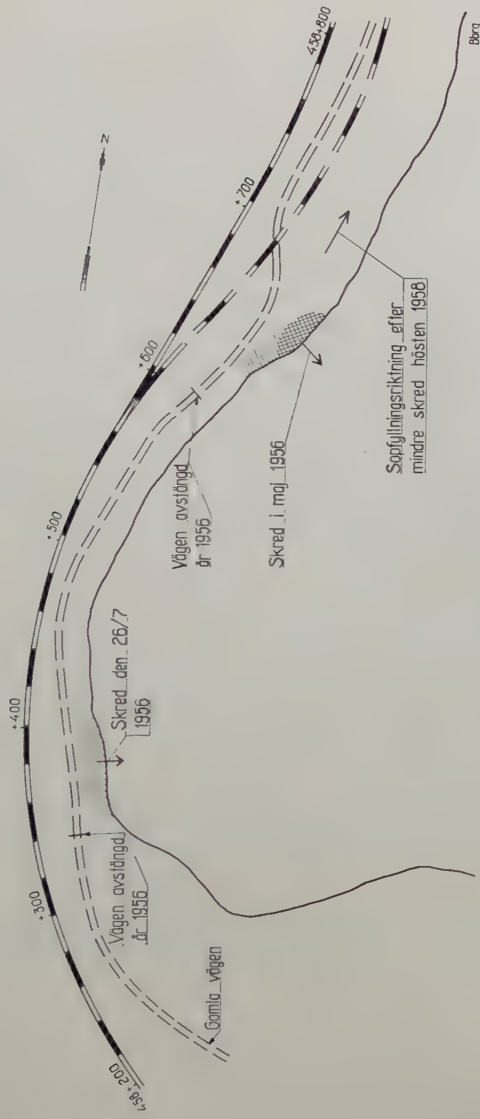


Fig. 10. Plan över tidigare småskred i skredområdets södra del.
Small slides before 1959 in the Kyrkviken area.

stort makadamupplag. Ehuru den till stor del ligger på berg eller »fastmark» är det ingen tvekan om, att den i viss utsträckning belastat de lösa sedimenten. Med hänsyn till de resultat som hittills framkommit beträffande kvicklerans uppträdande i Kramforssedimenten kan risker uppstå vid dylika belastningar, men kan upplaget, på grund av sitt läge i förhållande till skredplatsen, i detta fall knappast ha varit en utlösande faktor. Beträffande faktor 4 kan endast sägas, att den liksom landhöjningen innebär en kontinuerlig ökning av den i anspråk tagna skjuvpåkänningen i presumtiva glidytor. Sedimentationen sker huvudsakligen från norr och söder och har undervattensdelen av skredet huvudsakligast belastats av deltasediment norrifrån. Slutligen har vi soptippen. Här har vid senare efterforskning befunnits att denna skridit ett flertal gånger (fig. 10). Det torde inte råda något tvivel om, att soptippen under flera års tid ackumulerat ett instabilt tillstånd i viken, och att utryckningen av massor i januari 1959 varit tungan på vågen varvid storskreden utlösts. Detta oaktat skulle nog ett skred genom landhöjning och deltasedimentation ha utlösts, ehuru kanske först om några tiotal år, men åtgärder kunnat vidtagas, om man dessförinnan upptäckt det instabila läget. Det är dock mycket vanskligt att utföra stabilitetskalkyler i förhandenvarande jordarter. Det är fullt klart att skredet icke följt en cirkulärcylindrisk glidyta, utan att glidning skett efter ett svagare lager som är kvickt, i detta fall den på mjälan liggande sulfidbandade leran. Dylika glidytor har tidigare konstaterats (Eide 1955, Jakobson 1952, Odenstad 1951 och 1958). I detta fall kan skredförloppet, som varit bakåtgripande, tänkts ha försiggått på följande sätt. Först har en jordvolym med trapetsartad area glidit ut på detta lager och under glidningen uppblandats till en tätflytande välling, som runnit ut efter vikens botten ofta i en lutning ej överstigande 3°. Därefter har en ny volym blivit instabil och i sin tur runnit ut. Initialskredet och de sista efterskredshållorna kan till viss del av glidytan ha följt någon högre grads kurva t. ex. en cirkel eller ellips. Det torde här vara frågan om ett så kallat »progressive failure». Att skred 3 skedde genom en utglidning och successiv omröring på en sluttande skredbotten i form av en parallelltrapets med eventuellt den bakre parallella väggen något rundad, bestyrkes av ögonvittnesskildringen (Fellenius 1959).

Studiet av skredets förlopp och de topografiska och geologiska förhållandena på platsen fick till resultat, att geotekniska avdelningen sommaren 1959 igångsatte en systematisk undersökning med pejlingar över ställen med likartade förhållanden längs ostkustbanan. Denna undersökning är ännu icke slutförd.

Geotekniska avdelningen planerar att inom den närmaste tiden i sin meddelandeserie utgiva en mera detaljerad rapport över skredet.

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Vårmötet 1960

Svenska föreningens för lerforskning vårmöte anordnades i samarbete med Svenska geotekniska föreningen och hölls i Stockholm den 13 maj 1960.

Ordf. hälsade de närvarande välkomna. Till ledamöter i valnämnden omvaldes fil. dr T. Hagerman, sammankallande, civiling. Å. Grudemo och civiling. G. Lindskog. Till revisorer omvaldes laborator K.-I. Skärblom och statsgeolog E. Mohrén.

Den av årsmötet 1959 till styrelsen remitterade frågan om ev. arvode till föreningens sekreterare behandlades. Från styrelsen förelåg förslag, att sekreteraren förutom fri resa även skulle åtnjuta fri förtäring i samband med föreningssammanträden. Något arvode därutöver skulle med hänsyn till föreningens begränsade ekonomiska resurser tills vidare inte utbetalas. Ordf. framförde ett förslag från fru A. M. Asklund, att sekreteraren skulle erhålla ekonomisk ersättning, ifall han måste ta tjänstledighet för att bevista föreningssammanträde. Mötet beslöt i enlighet med styrelsens och fru A. M. Asklunds förslag.

Övering. J. Osterman, Statens geotekniska institut, Stockholm, höll därefter föredrag över ämnet: Synpunkter på stabiliteten hos erslänter. I den efterföljande diskussionen, som leddes av överinsp. B. Jakobson, yttrade sig hrr S. Flodin, J. Olsson, S. Odenstad, T. Kallstenius, G. Beskow, I. Th. Rosenqvist, B. Löfquist, E. Saare och föredragshållaren. Ett autoreferat av föredraget publiceras i detta häfte.

Kand. R. Söderblom, Statens geotekniska institut, Stockholm, höll föredrag över ämnet: Nyare rön angående uppkomst av kvicklera. I diskussionen yttrade sig hrr G. Assarsson, I. Th. Rosenqvist, E. Sandegren, K.-I. Skärblom och föredragshållaren. Ett autoreferat av föredraget publiceras i detta häfte.

Prof. I. Th. Rosenqvist, Institutt for geologi, Oslo, höll föredrag även ämnet: Mekaniska egenskaper hos montmorillonitiska och illitiska leror beroende på Na/K-förhållandet i porvattnet. I anledning av föredraget yttrade sig fru A. M. Asklund samt hrr G. Assarsson, G. Beskow, T. Kallstenius, S. Odenstad och föredragshållaren.

Byrådir. E. Sandegren, Kungl. Järnvägsstyrelsen, Stockholm, höll föredrag över ämnet: Skredet vid Kyrkviken febr. 1959. I disskussionen yttrade sig hrr S. Odenstad, G. Assarsson, T. N. A. Jerbo, G. Beskow, B. Fellenius och föredragshållaren. Ett autoreferat av föredraget publiceras i detta häfte.

Ordf. tackade dagens föredragshållare och förklarade sammanträdet, som hade samlat ett 50-tal deltagare, avslutat.

Notis

IV Nordiska geologiska vintermötet

Det IV Nordiska geologiska vintermötet hölls i Uppsala 7—9 januari 1960 med 122 deltagare. Programmet och arrangemangen hade på ett utomordentligt förtjänstfullt sätt ordnats av den lokala kommittén d. v. s. i första hand prof. Erik Norin och fil. lic. Bengt Lindqvist.

Mötena hölls på den nya geologiska institutionen vid Kåbovägen, och den gemensamma middagen för 135 personer intogs på Smålands Nation andra dagens kväll.

Mötet öppnades torsdagen den 7 januari kl 11 i stora föreläsningssalen varvid enligt tradition den avgående ordföranden professor Kalervo Rankama föreläste över ämnet »Om tektiter». Efter lunch fortsatte därefter förhandlingarna på två sektioner enligt följande.

Torsdag 7 januari

Sektion I

Pentti Eskola: Urbergets regeneration under karelisk orogenes.
N. Magnusson: Det svenska urbergets åldersschema.
P. H. Reitan: Varme punkter (»hot spots») — av betydning for metamorf omkrystallisering og lokale faciesvariasjoner.
P. H. Lundegårdh: Naggenkvartsiten — en arenit i Härnöseriens botten.
Chr. Oftedahl: Om Jotuneruptivenes dannelse og beslektede problemer i Kaledonidene.
B. Dietrichson: Intakte rekrystalliserte bergartsmasser med ultrabasisk til intermediaer sammensetning og kontaktsone, langs Jotunnoritdekkets bevegelsessone i Øst-Jotunheimen.
H. v. Eckermann: 1) Borengit, en extremt kalirik ny gångbergart från Alnön.
— 2) En vulkanbreccia inom Alnöns centrala sövitområde.
W. Wahl: Om pallasitproblemet.

Sektion II

B. Järnefors: Om lerlagerföljder och lertyper i Götaälvdalen och deras fysikaliska egenskaper.
T. Sorgenfrei: Geologi og salt grundvand i Danmark.
S. Skjeseth: Kambro-silur-bergartens hydrogeologi i Oslofeltet.
G. Knutsson: Studier av grundvattenströmning med hjälp av radioaktiva spårämnen.
K. Egede Larssen: Om strand-forskyvning i Vestfold, Ytre Oslofjord.
Å. Hörnsten: Högsta kustlinjen, H. K., i norra Ångermanland.

Fredag 8 januari

Sektion I

H. Koark: Något om Norra Kärr.
E. Bondesen: Et strukturelt kronologisk studie i det sydvestgrønlandske grundfjeld.
N. Henriksen: En strukturel analyse af en forkastning i det SW-Grønlandske grundfjeld.
B. Asklund: Nytt från fjällranden i gränsområdet mellan Ångermanland, Västerbotte och Jämtland.

N. Spjeldnæs: Datering av den kaledonske foldings faser.
H. Helfrich: Åretraktens geologi.
A. Strömberg: Tektonik i en sydlig del av de svenska Kaledoniderna.
P. Ljunggren: Radioaktivt nedfall.
G. Kautskty: Arkeisk paleo-geografi i Skelleftefältet.
F. M. Vokes: Tinnsten i en nord-norsk kismalm.
A. M. Byström-Asklund: K/A åldrar av mineral separerade ur bentonitlagren i Kinnekulle.
K. Fredriksson: Försök med geokemisk prospektering i Stekenjokk-området.
M. Lindström: Deformationsspår i Kaledoniderna. Avsnittet Torneträsk—Balvatnet.

Sektion II

V. Veltheim: Om Bottenhavets berggrundskartering med hjälp av bottenprov och ekolodning.
E. Roxström: En ny apparat för orientering av diamantborrkärnor.
T. Hagerman: Iakttagelser över berggrund och tektonik i samband med nuvarande byggnation i Stockholmstrakten.
C.-O. Morfeldt: Några kvartärgeologiska iakttagelser i samband med schaktningar och bergarbeten i Stockholm.
N. Edelman: Sprickräkning och topografi i Nyhamnsområdet.
G. Engström: Nya rön om berggrunden i Gävle.
B. Collini: En brantstående »inneslutning» i Höörsandstenen.
F. Brotzen: Daniens faciesförändringar i Sverige.
I. Hessland: Prekvartär mikropaleontologisk forskning i Sverige under senare tid.
G. Erdtman: Apokraterna — sporanalytiska miljöindikationer.
J. R. Praglowski: Inbäddningsmedier och deras betydelse vid sporanalys.
E. Hult De Geer: Issjödräneringar, kusthydrografi och megavarv (GFF 1957, E.u.G./ 1959).
R. Feyling-Hansen: Postglacial strandforskyvning i det centrale Spitzbergen.
S. Florin: Efter Vråtid.

Lördagen den 9 januari ägnades åt besök på den geografiska institutionen, som visades under ledning av professor Filip Hjulström, och de kemiska och fysiska institutionerna.

Mötet avslutades därefter i den stora föreläsningssalen, varvid danskarna inbjöd till vintermöte i Köpenhamn januari 1962. Till ny svensk medlem av arbetsutskottet efter professor F. E. Wickman hade utsetts professor Gerhard Regnéll.

Frans E. Wickman

Recensioner

Beno Gutenberg: Physics of the Earth's Interior. International Geophysics Series, Vol. 1, Academic Press, Inc., New York and London, 1959. XII + 240 pp. Price $ 8.50.

At the same time as this book is the first volume in the new International Geophysics Series of the Academic Press, it is unfortunately also the last book of Beno Gutenberg's active pen. The book appeared in print only a little more than two months before its author's death in January, 1960.

Gutenberg had a leading position in geophysics, especially seismology, for half a century, and he produced several hundred scientific papers and several books. His production will also be of outstanding importance for many years to come. The present book has a high authoritative value, as its author has made contributions of fundamental importance in almost every field treated in the book.

There are obviously several problems connected with the presentation of such a comprehensive subject as the physics of the earth's interior in so limited a number of pages. In the preface, the author says, that the uneven familiarity of any geophysicist with the many fields of natural science involved, favours their uneven treatment. This is reflected e.g. in the limited discussion of the earth's magnetism (pp. 117—118 and pp. 215—221) compared to the extensive treatment of temperatures in the earth (pp. 121—146). The limited space and Gutenberg's ambition to give complete accounts of especially the numerous recent results have led to a very concentrated presentation, which in several instances is an enjoyable reading only to specialists in the respective fields, but not possible to grasp for the non-specialist, unless he proceeds to the original literature. This makes the book too difficult for a beginner. It could be suitable as a text-book on the graduate student level, but then a more thorough treatment of basic physics behind the phenomena would have been desirable. For the professional geophysicist the book has a given value, especially thanks to the extensive up-to-date literature references (559 in all), the numerous tables (34 in all) with great amounts of numerical information, as well as to the emphasis on remaining problems. On the whole, the exposition is clear, although it would have been an advantage, if the author had been given more space, so as to make the presentation less concentrated in some cases.

In the introductory chapter 1 the difficulties in investigations of the earth's interior are emphasized and the author warns the readers for overestimation of the accuracy of the results. The accuracy is limited by the fact that generally only indirect methods can be used, and too far-reaching extrapolations of laboratory measurements or of theoretical considerations may lead to erroneous conclusions. In many cases the increased number of observations recently have invalidated earlier conclusions, which were considered as reliable and correct. The ideas expressed have a personal touch and are based on a long experience.

In chapter 2 the main features of the earth's internal structure are given. We find that Gutenberg's velocity determinations for the earth's interior in 1914 were remarkably accurate, and that later achievements have mainly improved details, although of great importance, in the early curves. The three following chapters 3, 4, and 5 deal with the main portions of the earth's interior, i.e. crust, mantle, and core resp. The most important methods of determining properties of layers in the crust are based on the investigation of elastic waves produced either by earthquakes (body waves, channel waves, and surface waves) or by artificial explosions. On the other hand, gravimetric crustal studies are usually not very reliable, owing to the uncertainty of the assumptions made, but may be useful in combination with seismic studies and rock density determinations. Such combined studies have revealed the existence of mountain roots and have elucidated the complicated but regular structure of the Pacific arcs.

The mantle (chapter 4) occupies the region below the crust down to the core in 2 900 km depth. Contrasting with many geophysicists, the author believes that there is no definite indication of any first-order discontinuity in the mantle. An increasing number of evidences shows the existence of a low-velocity zone in the upper mantle (down to 200—250 km depth); it is consistent with all available observations, including those of the controversial »20°-discontinuity». There are a few misprints in the mathematical derivations on pp. 90—91: eq. (4.6) for the bulk modulus should read $k = \varrho \frac{dp}{d\varrho}$; in eq. (4.7), first equation, the right-hand side should have a minus sign; in eq. (4.11) the first term on the right-hand side, last member, should have a minus sign.

In chapter 5, Gutenberg has succeeded in giving a clear exposition of the extremely complicated wave propagation phenomena, which occur due to the existence of the cores. This is one of the fields, in which the author is a world authority and in which he has made fundamental contributions from 1914 up to his last years. Many of the recent results depend on records of short-period high-magnification seismographs, of which a denser net-work has been in existence only during the last decade. Very much increased precision will be obtained from the records of large, controlled explosions, which, however, are not mentioned.

The uncertainties in our knowledge of the temperature and the thermal processes in the earth (chapter 6) are considerable, and contrast markedly with our relatively reliable knowledge of velocities and wave propagation in the interior. The ignorance of the thermal properties increases rapidly as we go deeper than a few meters or hundreds of meters below the surface. Nevertheless, recent years have brought several new results with at least some reliability, among which we may mention the following:

(1) radiation plays a rôle for the heat transfer in the mantle besides conduction and subcrustal currents;
(2) the heat flow is the same in continents as in ocean bottoms;
(3) the heat from volcanoes is negligible compared to the total heat flow through the earth's surface;
(4) the crust and the upper mantle may be cooling, but the lower mantle and the core may be warming up at present;
(5) the temperature at the earth's center is probably around 3 000°—4 000°.

Other physical properties of the earth's interior (density, pressure, gravity, elastic parameters) are dealt with in chapters 7 and 8. The density is much better known than the temperature, especially in the mantle, as there are more restrictions imposed on density determinations than on temperature determinations. When the vertical variations of wave velocities and density are known, the determination of pressure, gravity, and elastic parameters reduces to relatively simple computations.

The nonelastic processes in the earth (chapter 9) include a large variety of problems, such as attenuation of elastic waves, yield strength, postglacial uplift, subcrustal currents, strain-rebound characteristics of earthquakes, continental drift, secular movements of the poles. These are problems of great importance for our understanding of the behaviour of the earth, but they are also extremely difficult to deal with. The author has reason to mention repeatedly the inherent difficulties of the problems and to emphasize our present lack of accurate knowledge.

The illustrations (55 in all) are instructive, and it is a definite merit that in graphs illustrating e.g. the vertical variation of physical properties in the earth, not only one solution is given but usually quite a number of solutions. The illustrations demonstrate at a glance the uncertainties in our knowledge about the earth's interior. The book has an attractive style and very few misprints, which adds further to its merits.

Markus Båth

Margaret S. Bishop: Subsurface Mapping. J. Wiley & Sons, New York—London. 198 pp. 1960; price $ 5.75.

This attractively produced little volume contains no essentially new information, but has the advantage of bringing together a number of topics under the one cover. The book purports to have arisen from a course in subsurface geology at the University of Houston, and the scope and mode of presentation do not greatly deviate from lecture form. This is in a way a drawback, for the text is strongly flavored to suit local conditions. In order to meet the requirements of the international market the reviewer feels that the material should have been more thoroughly digested and consideration also taken to the non-American literature. In a long list of literature on mapping, sedimentology, paleoecology, etc. not a single non-English language paper, publication or book is mentioned, and only one of these is non-American. The title »Subsurface mapping» also seems to be somewhat of a misnomer, for surface procedures form an important part of the book. The authoress is seldom critical, being almost always content to relate what others have done.

There is, however, a dearth of literature on the subject and the volume represents a definite need. Subjects treated include the preparation of map contours, cross sections, topographic maps, stratigraphic terminology, structure, isopach maps, facies maps, and paleogeographic, geochemical and geophysical maps. Some of the treatments are unfortunately patchy. For example, photogrammetry is dismissed in less than half a sentence. As the book is supposed to treat subsurface methods, this may be more or less in order, but why treat topographic methods at all if this is the case? The section on stratigraphic terminology is also unsatisfactory.

Subsurface mapping will provide a usable adjunct to a university course in surveying and preparation of geologic maps, providing its shortcomings are realized. Dr. Bishop scores a point for the clear prose.

R. A. Reyment

Carl O. Dunbar: Historical Geology. J. Wiley & Sons, New York—London. Second Edition. 500 pp., 406 figs. 1960; price $ 7.95.

This book, which has been appearing in various forms since 1915, hardly needs any introduction and the present review is therefore concerned with an examination of such additions as have been made since the 1949 edition. The most striking differences between the two publications concern the larger size, the high standard and large number of photographs and other illustrations, and the attractive printing work of the 1960 version. The increased page size has permitted partition of the text into two columns as well as an overall enlargement of the figures. The subject matter has been most carefully gone over, sifted and simplified. This is enhanced by the eye-catching headings. The result is that the volume is very easy to read.

Each chapter is opened with a large »atmosphere picture» of high quality. It is, however, a little surprising to see the same photograph in a less satisfactory, reduced version, reproduced further on in the same section. The literature references have been brought up to date in varying degrees. For example, one chapter is provided with a good coverage of Soviet literature, whereas others completely lack reference to important non-American work. In connexion with the larger page size it should be observed that some of the magnification figures have not been corrected (e.g. fig.

116, and pl. 10 on p. 241). There are occasional printing errors, some of which do not occur in the 1949 edition. The fossil names are mostly in accordance with modern taxonomic points of view, although *Texanites texanus*, a lower Santonian species, is still referred to the Albian genus *Mortoniceras* (p. 346). An occasional Latin ending does not acccord with the gender of the generic name.

Chapter 2 includes an interesting and timely synopsis of recent advances in methods of radioactive dating and chapter 5 is provided with a short biochemical discussion. The correlation charts, formerly placed in an appendix, now occur up in the main body of the text. As regards the contents of the chapters on the various systems it may be mentioned that Gotland still does not rate a mention, which is unfortunate, as even the junior student is sure to run into the term Gotlandian somewhere in his readings. Of interest to the Scandinavian reader is the fact that Jarvik's work on late Devonian tetrapods is taken into account. A few other non-American features are included cursorily, but there does not seem to have been any sort of plan behind the selection of the material taken up. A surprising omission is Arkell's book on the Jurassic geology of the world and the information contained therein.

As regards the Scandinavian student the volume may be heartily recommended as a quick way of learning much about the elements of North American historical geology. Unfortunately its restricted scope will not permit it to threaten the standard course books at present in use in this part of the world.

R. A. Reyment

Mötet den 5 maj 1960

Närvarande 19 personer.

T.f. ordföranden, hr Fromm, förklarade sammanträdet öppnat och meddelade att Styrelsen till ledamöter i Föreningen invalt ingenjör Heino Roosaar, Stockholm, föreslagen av hrr Caldenius och Hagerman, och vidare fil. mag. Veikko Lappalainen, Otaniemi, Finland, föreslagen av fru Toini Mikkola och hr Gabrielson.

Häfte nr 2 av innevarande årgång av Förhandlingarna beräknas bl. a. på grund av den stora anhopningen av tryck för sommarens internationella geologkongress utkomma först omkring den 1 juli.

På grund av de talrika exkursionerna i samband med nämnda kongress kommer Föreningen ej att anordna sedvanlig maj-exkursion.

Intendenten fil. dr. Henning Horn af Rantzien höll därefter ett föredrag med titeln: Några synpunkter på tertiära kransalger som stratigrafiska indikatorer.

I anledning av föredraget yttrade sig hrr Fromm, Hessland, Martinsson och föredragshållaren.

Geolognytt

Rapport

angående 1960 års geologkongress och upprättandet av en internationell union i geologi, ansluten till ICSU (International Council of Scientific Unions)

Kongressen, som organiserades gemensamt av de nordiska länderna, pågick i Köpenhamn under tiden 15—25 augusti 1960. Den hade samlat mer än 3 000 deltagare och föregicks och efterföljdes av exkursioner i samtliga nordiska länder.

I de svenska exkursionerna deltogo mellan 500 och 600 geologer från hela världen. Samtliga 21 exkursioner genomfördes programenligt. Såvitt jag kunnat utröna, har deltagarna varit nöjda med vad som visats och allmänt har vitsordats, att exkursionerna givit det avsedda utbytet. För det framgångsrika arbetet är främst att tacka exkursionsledarna, både utom och inom SGU, som genom i många fall uppoffrande insatser gjort det möjligt att genomföra det ofta hårda programmet. Vidare har stor välvilja visats av företag och enskilda, som medverkat både i organisationsarbetet och genom gästfrihet gentemot exkursionsdeltagarna. Genomförandet av själva reseprogrammet (förhyrning av fordon, inkvartering m. m.) har anförtrotts Reso, som med heder skilt sig från uppgiften.

Med Kungl. Maj:ts medgivande har förberedelsearbetet kunnat utföras i tjänsten med anlitande av till SGU:s förfogande stående medel. Även för trycket av guiderna har statsmedel kunnat tagas i anspråk. Däremot har eftersträvats att göra själva exkursionerna självfinansierade genom en lämplig avvägning av deltagarnas avgifter. Inkomsterna och utgifterna för exkursionerna torde balansera på ungefär en halv million kronor. Även om räkenskaperna ännu är långt ifrån avslutade finnes anledning förmoda, att det hela skall gå ihop.

Det ventenskapliga arbetet under kongressen var fördelat på ett tjugotal sektioner. Många ha direkt positiva erfarenheter av arbetet inom sektionerna. Ett påtagligt framsteg var, att föredragen kunde presenteras tryckta vid kongressen. Det saknades emellertid inte kritiska röster, som särskilt vände sig mot att den utmätta tiden i för stor utsträckning togs i anspråk av föredrag av ojämn kvalitet och att alltför litet utrymme gavs till diskussion av brännande problem. Vidare påtalades språksvårigheterna (kongressen har sex officiella språk). I Bureau och Council kunde dessa svårigheter överbryggas genom simultantolkning. Betydelsen av den personliga kontakten mellan geologer från hela världen med likartade problem underströks allmänt.

I Bureau, i vilken ingick endast en huvuddelegat från vart land, och i Council, där samtliga (huvud)delegater hade säte, upptogos till behandling organisatoriska och förvaltningsmässiga frågor. Ett av de viktigaste spörsmålen var bildandet av en internationell union för geologi. Denna fråga hade aktualiserats på tidigare kongresser men inte kunnat föras framåt.

Då motiven för bildandet av en sådan union inom den nordiska organisationskommittén ansågs synnerligen starka, enades man om att med kraft söka föra frågan framåt vid Köpenhamnskongressen, vid vilken en allsidig representation från världens geologer kunde påräknas. Motiven härför var bl. a. behovet av ett mellan kongresserna arbetande organ med vissa ekonomiska resurser, som kunde ta initiativet till ordnande av symposier, medverka vid det internationella utbytet av geologer och i samarbetet med angränsande naturvetenskaper. Härigenom kunde vidare en naturlig anknytning erhållas till det internationella samarbetsorganet på området, The International Council of Scientific Unions (ICSU) med de fördelar detta innebar. Några var inte ens främmande för tanken att ersätta de alltför stora kongresserna med unionen, som borde ha bättre möjligheter att genom ordnandet av symposier samla en mindre krets av geologer kring speciella problem.

Till kongressen hade i stadgeenlig ordning framlagts förslag, syftande till bildandet av en union. Från Schweiz och Holland hade påyrkats tillsättandet av en kommission för studium av unionsfrågan, medan brittiska nationalkommittén för geologi framlagt ett direkt förslag, innefattande jämväl ett utkast till stadgar för unionen.

Vid den inledande diskussionen i Bureau och Council framkom snart vissa meningsskiljaktigheter i unionsfrågan. Från många håll underströks önskvärdheten av att säkra kongressernas fortbestånd som ett mycket värdefullt instrument vid det internationella samarbetet. Några ifrågasatte behovet av en union vid sidan av kongressen. För frågans behandling under kongressen tillsattes en särskild kommission i vilken ingick — förutom representanter för kongressens presidium — huvuddelegaterna för Ryssland, Polen, Indien, Canada, USA, England, Frankrike, Österrike och Holland, en från vart land.

Vid kommissionens arbete visade det sig snart att — om ett enigt förslag skulle kunna framläggas — målsättningen för arbetet under kongressen måste begränsas till att få till stånd en principrekommendation till bildandet av en union med angivande av målsättningen. Med en överväldigande majoritet (200—300 röster för och endast 3 emot) antogs det förslag, som kommissionen enats om, därvid målsättningen preciserades med följande ord.

»The aims and objects of the International Union of Geology shall be:

1) to promote and encourage the study of geological problems,
2) to facilitate international cooperation in geology and related sciences,
3) to provide continuity in international cooperation in Geology,
4) to assist the International Geological Congresses, it being understood that the long established activities of the Congresses shall be safeguarded.»

Tillika uppdrogs åt den kommission, som behandlat frågan vid kongressen, att utarbeta stadgar för unionen, därvid arbetet skulle så bedrivas, att en inbjudan till resp. stater kunde utgå på våren 1961. Anledning finns att förmoda, att ICSU kommer att på allt sätt underlätta bildandet av Unionen.

I övriga må beträffande kommissionens kommande arbete här nämnas följande.

Kommissionen, som härefter arbetar som »the Organizing Committee of the International Union of Geology», har följande medlemmar:

N. Belyaevsky, Ryssland
W. Smulikowski, Polen
B. C. Roy, Indien
J. M. Harrison, Canada
T. B. Noland, USA
L. Hawkes, England
R. Laffitte, Frankrike
E. Clar, Österrike
H. M. E. Schürmann, Holland
V. Marmo, Finland
A. Noe-Nygaard, Danmark
J. A. Dons, Norge
T. Sorgenfrei, Danmark
K. A. Lindbergson, Sverige

Kongressens sekretariat i Köpenhamn skall fungera som organisationskommittens sekretariat. Den 15 september 1960 utsändes en skrivelse till de skilda staternas nationalkommittéer och huvuddelegater med begäran om yttrande och förslag till statuter. Svaren skall ha inkommit till den 15 oktober. Därefter sammanställas och bearbetas dessa, varefter en förberedande överarbetning skall äga rum i en mindre krets i *Helsingfors* den 28—29 november 1960, till vilket möte även undertecknad är kallad. Kommittén i dess helhet skall sammanträda i *Stockholm* den 28—29 december 1960. Om allt går efter beräkning borde kommittén därvid kunna enas om statuter för unionen och inbjudan därefter utgå till bildandet av en union i geologi. Platsen för ett konstituerande möte har ännu icke diskuterats.

Slutligen må här nämnas, att Indien och Nya Zeeland båda önskade anordna 1964 års geologkongress. Med en klar majoritet (ungefär 2/3) beslöt kongressen antaga Indiens inbjudan.

Stockholm den 23 september 1960.

K. A. Lindbergson

En försöksorganisation tillämpas enligt Riksdagens beslut f. o. m. 1 juli 1960 vid Sveriges geologiska undersökning. Tre byråer inrättas med följande t. f. byråchefer, nämligen

Kartbyrån, professor G. Lundqvist
Allmänna byrån, professor B. Asklund
Malmbyrån, docent G. Kautsky.

Nyheter från Sveriges Geologiska Undersökning

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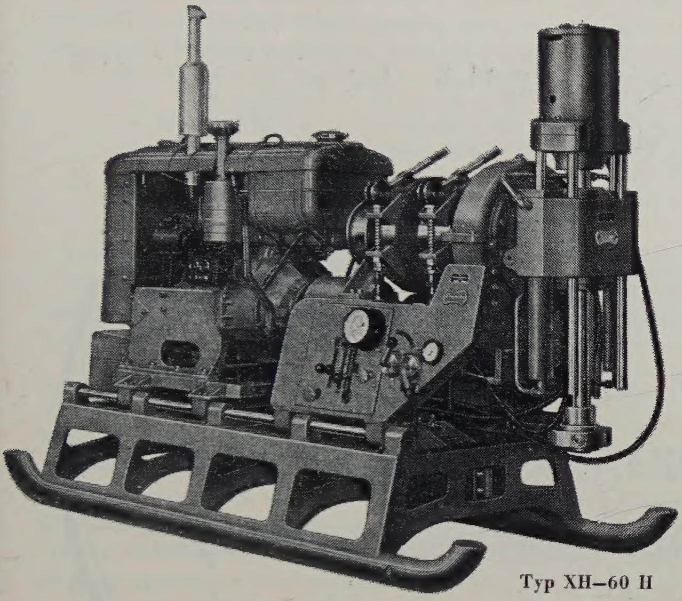

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Contents

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LINDSTRÖM, M.: On Some Sedimentary and Tectonic Structures in the Ludlovian Colonus Shale of Scania 319

WÆRN, B.: Bentonit och fjärrkonnektion. Anmärkningar med anledning av N. Spjeldnæs' uppsats "Silurian bentonites from Gotland" 342

Meddelande från Svenska föreningen för lerforskning 345

OSTERMAN, J.: Views on the Stability of Clay Slopes 346

SÖDERBLOM, R.: Aspects on Some Problems of Geotechnical Chemistry, Part II 367

SANDEGREN, E.: Skredet vid Kyrkviken februari 1959 382

Vårmötet 1960 397

Notis—Note:

IV Nordiska geologiska vintermötet 398

Recensioner—Reviews:

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